GATE 2014

Electrical Engineering

Topicwise Solved Paper

2013 - 2000

RK Kanoida & Ashish Murolia

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ENGINEERING MATHEMATICS

YEAR 2013 — ONE MARK

MCQ 1.1.1 Given a vector field $\vec{F} = y^2x\vec{a}_x - yz\vec{a}_y - x^2\vec{a}_z$, the line integral $\int \vec{F} \cdot d\vec{l}$ evaluated along a segment on the x-axis from $x = 1$ to $x = 2$ is

(A) -2.33 (B) 0

(C) 2.33 (D) 7

MCQ 1.1.2 The equation $\begin{bmatrix} 2 & -2 \\ 1 & -1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$ has

(A) no solution (B) only one solution $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$

(C) non-zero unique solution (D) multiple solutions

MCQ 1.1.3 Square roots of $-i$, where $i = \sqrt{-1}$, are

(A) i, $-i$

(B) $\cos\left(-\frac{\pi}{4}\right) + i\sin\left(-\frac{\pi}{4}\right)$, $\cos\left(\frac{3\pi}{4}\right) + i\sin\left(\frac{3\pi}{4}\right)$

(C) $\cos\left(\frac{\pi}{4}\right) + i\sin\left(\frac{3\pi}{4}\right)$, $\cos\left(\frac{3\pi}{4}\right) + i\sin\left(\frac{\pi}{4}\right)$

(D) $\cos\left(\frac{3\pi}{4}\right) + i\sin\left(-\frac{3\pi}{4}\right)$, $\cos\left(-\frac{3\pi}{4}\right) + i\sin\left(\frac{3\pi}{4}\right)$

MCQ 1.1.4 The curl of the gradient of the scalar field defined by $V = 2x^2y + 3y^2z + 4z^2x$ is

(A) $4xy\vec{a}_x + 6yz\vec{a}_y + 8zx\vec{a}_z$

(B) $4\vec{a}_x + 6\vec{a}_y + 8\vec{a}_z$

(C) $(4xy + 4z^2)\vec{a}_x + (2x^2 + 6yz)\vec{a}_y + (3y^2 + 8zx)\vec{a}_z$

(D) 0

MCQ 1.1.5 A continuous random variable X has a probability density function $f(x) = e^{-x}$, $0 < x < \infty$. Then $P\{X > 1\}$ is

(A) 0.368 (B) 0.5

(C) 0.632 (D) 1.0

YEAR 2013 — TWO MARKS

MCQ 1.1.6 When the Newton-Raphson method is applied to solve the equation $f(x) = x^3 + 2x - 1 = 0$, the solution at the end of the first iteration with the initial value as $x_0 = 1.2$ is

(A) -0.82 (B) 0.49

(C) 0.705 (D) 1.69

MCQ 1.1.7 A function $y = 5x^2 + 10x$ is defined over an open interval $x = (1, 2)$. Atleast at one point in this interval, dy/dx is exactly

(A) 20 (B) 25

(C) 30 (D) 35

MCQ 1.1.8 $\oint \frac{z^2-4}{z^2+4}dz$ evaluated anticlockwise around the circle $|z-i|=2$, where $i=\sqrt{-1}$ is

(A) -4π (B) 0

(C) $2+\pi$ (D) $2+2i$

MCQ 1.1.9 A Matrix has eigenvalues -1 and -2. The corresponding eigenvectors are $\begin{bmatrix}1\\-1\end{bmatrix}$ and $\begin{bmatrix}1\\-2\end{bmatrix}$ respectively. The matrix is

(A) $\begin{bmatrix}1 & 1\\-1 & -2\end{bmatrix}$ (B) $\begin{bmatrix}1 & 2\\-2 & -4\end{bmatrix}$

(C) $\begin{bmatrix}-1 & 0\\0 & -2\end{bmatrix}$ (D) $\begin{bmatrix}0 & 1\\-2 & -3\end{bmatrix}$

YEAR 2012 ONE MARK

MCQ 1.1.10 Two independent random variables X and Y are uniformly distributed in the interval $[-1,1]$. The probability that $\max[X,Y]$ is less than $1/2$ is

(A) 3/4 (B) 9/16

(C) 1/4 (D) 2/3

MCQ 1.1.11 If $x=\sqrt{-1}$, then the value of x^x is

(A) $e^{-\pi/2}$ (B) $e^{\pi/2}$

(C) x (D) 1

MCQ 1.1.12 Given $f(z)=\frac{1}{z+1}-\frac{2}{z+3}$. If C is a counter clockwise path in the z-plane such that $|z+1|=1$, the value of $\frac{1}{2\pi j}\oint_C f(z)dz$ is

(A) -2 (B) -1

(C) 1 (D) 2

MCQ 1.1.13 With initial condition $x(1)=0.5$, the solution of the differential equation $t\frac{dx}{dt}+x=t$, is

(A) $x=t-\frac{1}{2}$ (B) $x=t^2-\frac{1}{2}$

(C) $x=\frac{t^2}{2}$ (D) $x=\frac{t}{2}$

YEAR 2012 TWO MARKS

MCQ 1.1.14 Given that $A=\begin{bmatrix}-5 & -3\\2 & 0\end{bmatrix}$ and $I=\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$, the value of A^3 is

(A) $15A+12I$ (B) $19A+30I$

(C) $17A+15I$ (D) $17A+21I$

MCQ 1.1.15 The maximum value of $f(x)=x^3-9x^2+24x+5$ in the interval $[1,6]$ is

(A) 21 (B) 25

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(C) 41 (D) 46

MCQ 1.1.16 A fair coin is tossed till a head appears for the first time. The probability that the number of required tosses is odd, is

(A) 1/3 (B) 1/2

(C) 2/3 (D) 3/4

MCQ 1.1.17 The direction of vector A is radially outward from the origin, with $|A| = kr^n$. where $r^2 = x^2 + y^2 + z^2$ and k is a constant. The value of n for which $\nabla \cdot A = 0$ is

(A) -2 (B) 2

(C) 1 (D) 0

MCQ 1.1.18 Consider the differential equation

$$\frac{d^2y(t)}{dt^2} + 2\frac{dy(t)}{dt} + y(t) = \delta(t) \text{ with } y(t)\Big|_{t=0^-} = -2 \text{ and } \frac{dy}{dt}\Big|_{t=0^-} = 0$$

The numerical value of $\frac{dy}{dt}\Big|_{t=0^+}$ is

(A) -2 (B) -1

(C) 0 (D) 1

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YEAR 2011 ONE MARK

MCQ 1.1.19 Roots of the algebraic equation $x^3 + x^2 + x + 1 = 0$ are

(A) $(+1, +j, -j)$ (B) $(+1, -1, +1)$

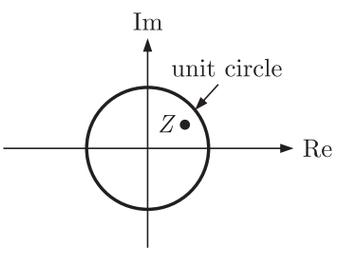
(C) $(0,0,0)$ (D) $(-1, +j, -j)$

MCQ 1.1.20 With K as a constant, the possible solution for the first order differential equation $\frac{dy}{dx} = e^{-3x}$ is

(A) $-\frac{1}{3}e^{-3x} + K$ (B) $-\frac{1}{3}e^{3x} + K$

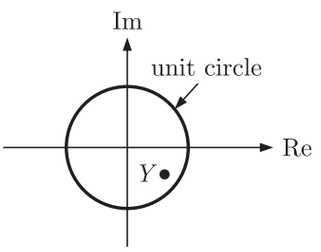
(C) $-\frac{1}{3}e^{-3x} + K$ (D) $-3e^{-x} + K$

MCQ 1.1.21 A point Z has been plotted in the complex plane, as shown in figure below.

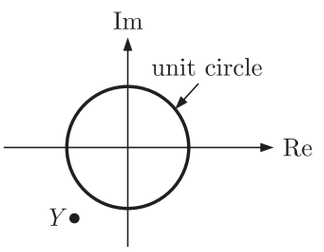


The plot of the complex number $Y = \frac{1}{Z}$ is

(A)



(B)



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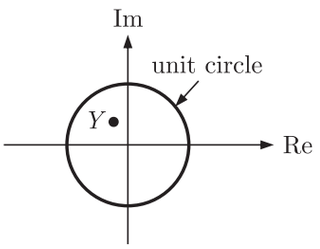
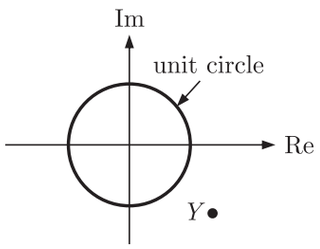
(C)



(D)



YEAR 2011 TWO MARKS

MCQ 1.1.22 Solution of the variables x_1 and x_2 for the following equations is to be obtained by employing the Newton-Raphson iterative method.

Equation (1) $10x_2 \sin x_1 - 0.8 = 0$

Equation (2) $10x_2^2 - 10x_2 \cos x_1 - 0.6 = 0$

Assuming the initial values are $x_1 = 0.0$ and $x_2 = 1.0$, the jacobian matrix is

(A) $\begin{bmatrix} 10 & -0.8 \\ 0 & -0.6 \end{bmatrix}$ (B) $\begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix}$

(C) $\begin{bmatrix} 0 & -0.8 \\ 10 & -0.6 \end{bmatrix}$ (D) $\begin{bmatrix} 10 & 0 \\ 10 & -10 \end{bmatrix}$

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MCQ 1.1.23 The function $f(x) = 2x - x^2 - x^3 + 3$ has

(A) a maxima at $x = 1$ and minimum at $x = 5$

(B) a maxima at $x = 1$ and minimum at $x = -5$

(C) only maxima at $x = 1$ and

(D) only a minimum at $x = 5$

MCQ 1.1.24 A zero mean random signal is uniformly distributed between limits $-a$ and $+a$ and its mean square value is equal to its variance. Then the r.m.s value of the signal is

(A) $\frac{a}{\sqrt{3}}$ (B) $\frac{a}{\sqrt{2}}$

(C) $a\sqrt{2}$ (D) $a\sqrt{3}$

MCQ 1.1.25 The matrix $[A] = \begin{bmatrix} 2 & 1 \\ 4 & -1 \end{bmatrix}$ is decomposed into a product of a lower triangular matrix $[L]$ and an upper triangular matrix $[U]$. The properly decomposed $[L]$ and $[U]$ matrices respectively are

(A) $\begin{bmatrix} 1 & 0 \\ 4 & -1 \end{bmatrix}$ and $\begin{bmatrix} 1 & 1 \\ 0 & -2 \end{bmatrix}$ (B) $\begin{bmatrix} 2 & 0 \\ 4 & -1 \end{bmatrix}$ and $\begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$

(C) $\begin{bmatrix} 1 & 0 \\ 4 & 1 \end{bmatrix}$ and $\begin{bmatrix} 2 & 1 \\ 0 & -1 \end{bmatrix}$ (D) $\begin{bmatrix} 2 & 0 \\ 4 & -3 \end{bmatrix}$ and $\begin{bmatrix} 1 & 1.5 \\ 0 & 1 \end{bmatrix}$

MCQ 1.1.26 The two vectors [1,1,1] and $[1, a, a^2]$ where $a = \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right)$, are

(A) Orthonormal (B) Orthogonal

(C) Parallel (D) Collinear

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YEAR 2010 ONE MARK

MCQ 1.1.27 The value of the quantity P, where $P = \int_0^1 xe^x dx$, is equal to

(A) 0 (B) 1

(C) e (D) 1/e

MCQ 1.1.28 Divergence of the three-dimensional radial vector field $\vec{r}$ is

(A) 3 (B) $1/r$

(C) $\hat{i}+\hat{j}+\hat{k}$ (D) $3(\hat{i}+\hat{j}+\hat{k})$

YEAR 2010 TWO MARKS

MCQ 1.1.29 A box contains 4 white balls and 3 red balls. In succession, two balls are randomly and removed form the box. Given that the first removed ball is white, the probability that the second removed ball is red is

(A) 1/3 (B) 3/7

(C) 1/2 (D) 4/7

MCQ 1.1.30 At $t = 0$, the function $f(t) = \frac{\sin t}{t}$ has

(A) a minimum (B) a discontinuity

(C) a point of inflection (D) a maximum

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MCQ 1.1.31 An eigenvector of $P = \begin{pmatrix} 1 & 1 & 0 \\ 0 & 2 & 2 \\ 0 & 0 & 3 \end{pmatrix}$ is

(A) $\begin{bmatrix} -1 & 1 & 1 \end{bmatrix}^T$ (B) $\begin{bmatrix} 1 & 2 & 1 \end{bmatrix}^T$

(C) $\begin{bmatrix} 1 & -1 & 2 \end{bmatrix}^T$ (D) $\begin{bmatrix} 2 & 1 & -1 \end{bmatrix}^T$

MCQ 1.1.32 For the differential equation $\frac{d^2x}{dt^2} + 6\frac{dx}{dt} + 8x = 0$ with initial conditions $x(0) = 1$ and $\left.\frac{dx}{dt}\right|_{t=0} = 0$, the solution is

(A) $x(t) = 2e^{-6t} - e^{-2t}$ (B) $x(t) = 2e^{-2t} - e^{-4t}$

(C) $x(t) = -e^{-6t} + 2e^{-4t}$ (D) $x(t) = e^{-2t} + 2e^{-4t}$

MCQ 1.1.33 For the set of equations, $x_1 + 2x_2 + x_3 + 4x_4 = 2$ and $3x_1 + 6x_2 + 3x_3 + 12x_4 = 6$. The following statement is true.

(A) Only the trivial solution $x_1 = x_2 = x_3 = x_4 = 0$ exists

(B) There are no solutions

(C) A unique non-trivial solution exists

(D) Multiple non-trivial solutions exist

YEAR 2009 ONE MARK

MCQ 1.1.34 The trace and determinant of a 2×2 matrix are known to be -2 and -35 respectively. Its eigen values are

(A) -30 and -5 (B) -37 and -1

(C) -7 and 5 (D) 17.5 and -2

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YEAR 2009 TWO MARKS

MCQ 1.1.35 $f(x,y)$ is a continuous function defined over $(x,y) \in [0,1] \times [0,1]$. Given the two constraints, $x > y^2$ and $y > x^2$, the volume under $f(x,y)$ is

(A) $\int_{y=0}^{y=1} \int_{x=y^2}^{x=\sqrt{y}} f(x,y)\,dxdy$ (B) $\int_{y=x^2}^{y=1} \int_{x=y^2}^{x=1} f(x,y)\,dxdy$

(C) $\int_{y=0}^{y=1} \int_{x=0}^{x=1} f(x,y)\,dxdy$ (D) $\int_{y=0}^{y=\sqrt{x}} \int_{x=0}^{x=\sqrt{y}} f(x,y)\,dxdy$

MCQ 1.1.36 Assume for simplicity that N people, all born in April (a month of 30 days), are collected in a room. Consider the event of at least two people in the room being born on the same date of the month, even if in different years, e.g. 1980 and 1985. What is the smallest N so that the probability of this event exceeds 0.5 ?

(A) 20 (B) 7

(C) 15 (D) 16

MCQ 1.1.37 A cubic polynomial with real coefficients

(A) Can possibly have no extrema and no zero crossings

(B) May have up to three extrema and upto 2 zero crossings

(C) Cannot have more than two extrema and more than three zero crossings

(D) Will always have an equal number of extrema and zero crossings

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MCQ 1.1.38 Let $x^2 - 117 = 0$. The iterative steps for the solution using Newton-Raphon's method is given by

(A) $x_{k+1} = \frac{1}{2}\left(x_k + \frac{117}{x_k}\right)$ (B) $x_{k+1} = x_k - \frac{117}{x_k}$

(C) $x_{k+1} = x_k - \frac{x_k}{117}$ (D) $x_{k+1} = x_k - \frac{1}{2}\left(x_k + \frac{117}{x_k}\right)$

MCQ 1.1.39 $\mathbf{F}(x,y) = (x^2 + xy)\,\hat{a}_x + (y^2 + xy)\,\hat{a}_y$. It's line integral over the straight line from $(x,y) = (0,2)$ to $(x,y) = (2,0)$ evaluates to

(A) -8 (B) 4

(C) 8 (D) 0

YEAR 2008 ONE MARKS

MCQ 1.1.40 X is a uniformly distributed random variable that takes values between 0 and 1. The value of $E\{X^3\}$ will be

(A) 0 (B) 1/8

(C) 1/4 (D) 1/2

MCQ 1.1.41 The characteristic equation of a $(3 \# 3)$ matrix P is defined as

$$a(\lambda) = |\lambda I - P| = \lambda^3 + \lambda^2 + 2\lambda + 1 = 0$$

If I denotes identity matrix, then the inverse of matrix P will be

(A) $(P^2 + P + 2I)$ (B) $(P^2 + P + I)$

(C) $-(P^2 + P + I)$ (D) $-(P^2 + P + 2I)$

MCQ 1.1.42 If the rank of a $(5 \# 6)$ matrix Q is 4, then which one of the following statement is correct ?

(A) Q will have four linearly independent rows and four linearly independent columns

(B) Q will have four linearly independent rows and five linearly independent

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columns

(C) QQ^{T} will be invertible

(D) $Q^{\mathrm{T}}Q$ will be invertible

YEAR 2008 TWO MARKS

MCQ 1.1.43 Consider function $f(x) = (x^2 - 4)^2$ where x is a real number. Then the function has

(A) only one minimum (B) only tow minima

(C) three minima (D) three maxima

MCQ 1.1.44 Equation $e^x - 1 = 0$ is required to be solved using Newton's method with an initial guess $x_0 = -1$. Then, after one step of Newton's method, estimate x_1 of the solution will be given by

(A) 0.71828 (B) 0.36784

(C) 0.20587 (D) 0.00000

MCQ 1.1.45 A is $m \# n$ full rank matrix with $m > n$ and I is identity matrix. Let matrix $A' = (A^{\mathrm{T}}A)^{-1}A^{\mathrm{T}}$, Then, which one of the following statement is FALSE ?

(A) $AA'A = A$ (B) $(AA')^2$

(C) $A'A = I$ (D) $AA'A = A'$

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MCQ 1.1.46 A differential equation $dx/dt = e^{-2t}u(t)$, has to be solved using trapezoidal rule of integration with a step size $h = 0.01$ s. Function $u(t)$ indicates a unit step function. If $x(0^-) = 0$, then value of x at $t = 0.01$ s will be given by

(A) 0.00099 (B) 0.00495

(C) 0.0099 (D) 0.0198

MCQ 1.1.47 Let P be a $2 \# 2$ real orthogonal matrix and $\vec{x}$ is a real vector $[x_1, x_2]^{\mathrm{T}}$ with length $\|\vec{x}\| = (x_1^2 + x_2^2)^{1/2}$. Then, which one of the following statements is correct ?

(A) $\|P\vec{x}\| \# \|\vec{x}\|$ where at least one vector satisfies $\|P\vec{x}\| < \|\vec{x}\|$

(B) $\|P\vec{x}\| \# \|\vec{x}\|$ for all vector $\vec{x}$

(C) $\|P\vec{x}\| \$ \|\vec{x}\|$ where at least one vector satisfies $\|P\vec{x}\| > \|\vec{x}\|$

(D) No relationship can be established between $\|\vec{x}\|$ and $\|P\vec{x}\|$

YEAR 2007 ONE MARK

MCQ 1.1.48 $x = \{x_1 \; x_2 \; g \; x_n\}^{\mathrm{T}}$ is an n-tuple nonzero vector. The $n \# n$ matrix $V = xx^{\mathrm{T}}$

(A) has rank zero (B) has rank 1

(C) is orthogonal (D) has rank n

YEAR 2007 TWO MARKS

MCQ 1.1.49 The differential equation $\frac{dx}{dt} = \frac{1-x}{\tau}$ is discretised using Euler's numerical integration method with a time step $\mathbf{3}\, T > 0$. What is the maximum permissible value of $\mathbf{3}\, T$ to ensure stability of the solution of the corresponding discrete time equation ?

(A) 1 (B) $\tau/2$

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(C) τ (D) 2τ

MCQ 1.1.50 The value of $\oint_C \frac{dz}{(1+z^2)}$ where C is the contour $|z - i/2| = 1$ is

(A) $2\pi i$ (B) π

(C) $\tan^{-1}z$ (D) $\pi i \tan^{-1}z$

MCQ 1.1.51 The integral $\frac{1}{2\pi}\int_0^{2\pi} \sin(t-\tau)\cos\tau d\tau$ equals

(A) $\sin t \cos t$ (B) 0

(C) $(1/2)\cos t$ (D) $(1/2)\sin t$

MCQ 1.1.52 A loaded dice has following probability distribution of occurrences

Dice Value	1	2	3	4	5	6
Probability	1/4	1/8	1/8	1/8	1/8	1/4

If three identical dice as the above are thrown, the probability of occurrence of values 1, 5 and 6 on the three dice is

(A) same as that of occurrence of 3, 4, 5

(B) same as that of occurrence of 1, 2, 5

(C) 1/128

(D) 5/8

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MCQ 1.1.53 Let $\mathbf{x}$ and $\mathbf{y}$ be two vectors in a 3 dimensional space and $<\mathbf{x},\mathbf{y}>$ denote their dot product. Then the determinant

$$\det\begin{bmatrix} <\mathbf{x},\mathbf{x}> & <\mathbf{x},\mathbf{y}> \\ <\mathbf{y},\mathbf{x}> & <\mathbf{y},\mathbf{y}> \end{bmatrix}$$

(A) is zero when $\mathbf{x}$ and $\mathbf{y}$ are linearly independent

(B) is positive when $\mathbf{x}$ and $\mathbf{y}$ are linearly independent

(C) is non-zero for all non-zero $\mathbf{x}$ and $\mathbf{y}$

(D) is zero only when either $\mathbf{x}$ or $\mathbf{y}$ is zero

MCQ 1.1.54 The linear operation $\mathbf{L}(\mathbf{x})$ is defined by the cross product $\mathbf{L}(\mathbf{x}) = \mathbf{b} \times \mathbf{x}$, where $\mathbf{b} = [0\ 1\ 0]^T$ and $\mathbf{x} = [x_1\ x_2\ x_3]^T$ are three dimensional vectors. The 3×3 matrix M of this operations satisfies

$$\mathbf{L}(\mathbf{x}) = M\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

Then the eigenvalues of M are

(A) $0, +1, -1$ (B) $1, -1, 1$

(C) $i, -i, 1$ (D) $i, -i, 0$

Statement for Linked Answer Question 46 and 47.

Cayley-Hamilton Theorem states that a square matrix satisfies its own characteristic equation. Consider a matrix

$$A = \begin{bmatrix} -3 & 2 \\ -2 & 0 \end{bmatrix}$$

MCQ 1.1.55 A satisfies the relation

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(A) $A+3I+2A^{-1}=0$ (B) $A^2+2A+2I=0$

(C) $(A+I)(A+2I)$ (D) $\exp(A)=0$

MCQ 1.1.56 A^9 equals

(A) $511A+510I$ (B) $309A+104I$

(C) $154A+155I$ (D) $\exp(9A)$

YEAR 2006 TWO MARKS

MCQ 1.1.57 The expression $V=\int_0^H \pi R^2(1-h/H)^2 dh$ for the volume of a cone is equal to

(A) $\int_0^R \pi R^2(1-h/H)^2 dr$ (B) $\int_0^R \pi R^2(1-h/H)^2 dh$

(C) $\int_0^H 2\pi rH(1-r/R)\,dh$ (D) $\int_0^R 2\pi rH\left(1-\frac{r}{R}\right)^2 dr$

MCQ 1.1.58 A surface $S(x,y)=2x+5y-3$ is integrated once over a path consisting of the points that satisfy $(x+1)2+(y-1)2=\sqrt{2}$. The integral evaluates to

(A) $17\sqrt{2}$ (B) $17\sqrt{2}$

(C) $\sqrt{2}/17$ (D) 0

MCQ 1.1.59 Two fair dice are rolled and the sum r of the numbers turned up is considered

(A) $\Pr(r>6)=\frac{1}{6}$

(B) Pr ($r/3$ is an integer) $=\frac{5}{6}$

(C) Pr ($r=8$; $r/4$ is an integer) $=\frac{5}{9}$

(D) $\Pr(r=6$; $r/5$ is an integer) $=\frac{1}{18}$

Statement for Linked Answer Question 60 and 61.

$\mathrm{P}=\begin{bmatrix}-10\\1\\3\end{bmatrix}, \mathrm{Q}=\begin{bmatrix}-2\\-5\\9\end{bmatrix}, \mathrm{R}=\begin{bmatrix}2\\-7\\12\end{bmatrix}$ are three vectors.

MCQ 1.1.60 An orthogonal set of vectors having a span that contains P, Q, R is

(A) $\begin{bmatrix}-6\\-3\\-6\end{bmatrix}\begin{bmatrix}4\\-2\\3\end{bmatrix}$ (B) $\begin{bmatrix}-4\\2\\4\end{bmatrix}\begin{bmatrix}5\\7\\-11\end{bmatrix}\begin{bmatrix}8\\2\\-3\end{bmatrix}$

(C) $\begin{bmatrix}6\\7\\-1\end{bmatrix}\begin{bmatrix}-3\\2\\-2\end{bmatrix}\begin{bmatrix}3\\9\\-4\end{bmatrix}$ (D) $\begin{bmatrix}4\\1\\1\end{bmatrix}\begin{bmatrix}1\\31\\3\end{bmatrix}\begin{bmatrix}5\\3\\4\end{bmatrix}$

MCQ 1.1.61 The following vector is linearly dependent upon the solution to the previous problem

(A) $\begin{bmatrix}8\\9\\3\end{bmatrix}\begin{bmatrix}4\\4\\5\end{bmatrix}$ (B) $\begin{bmatrix}-2\\-17\\30\end{bmatrix}\begin{bmatrix}13\\2\\-3\end{bmatrix}$

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YEAR 2005 ONE MARK

MCQ 1.1.62 In the matrix equation $P\mathbf{x} = \mathbf{q}$, which of the following is a necessary condition for the existence of at least on solution for the unknown vector $\mathbf{x}$

(A) Augmented matrix $[P\mathbf{q}]$ must have the same rank as matrix P

(B) Vector $\mathbf{q}$ must have only non-zero elements

(C) Matrix P must be singular

(D) Matrix P must be square

MCQ 1.1.63 If P and Q are two random events, then the following is TRUE

(A) Independence of P and Q implies that probability $(P + Q) = 0$

(B) Probability (P , Q) $ Probability (P) + Probability (Q)

(C) If P and Q are mutually exclusive, then they must be independent

(D) Probability $(P + Q)$ # Probability (P)

MCQ 1.1.64 If $S = \int_1^3 x^{-3} dx$, then S has the value

(A) $-\frac{1}{3}$ (B) $\frac{1}{4}$

(C) $\frac{1}{2}$ (D) 1

MCQ 1.1.65 The solution of the first order DE $x'(t) = -3x(t)$, $x(0) = x_0$ is

(A) $x(t) = x_0 e^{-3t}$ (B) $x(t) = x_0 e^{-3}$

(C) $x(t) = x_0 e^{-1/3}$ (D) $x(t) = x_0 e^{-1}$

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YEAR 2005 TWO MARKS

MCQ 1.1.66 For the matrix $p = \begin{bmatrix} 3 & -2 & 2 \\ 0 & -2 & 1 \\ 0 & 0 & 1 \end{bmatrix}$, one of the eigen values is equal to -2

Which of the following is an eigen vector ?

(A) $\begin{bmatrix} 3 \\ -2 \\ 1 \end{bmatrix}$ (B) $\begin{bmatrix} -3 \\ 2 \\ -1 \end{bmatrix}$

(C) $\begin{bmatrix} 1 \\ -2 \\ 3 \end{bmatrix}$ (D) $\begin{bmatrix} 2 \\ 5 \\ 0 \end{bmatrix}$

MCQ 1.1.67 If $R = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 1 & -1 \\ 2 & 3 & 2 \end{bmatrix}$, then top row of R^{-1} is

(A) $\begin{bmatrix} 5 & 6 & 4 \end{bmatrix}$ (B) $\begin{bmatrix} 5 & -3 & 1 \end{bmatrix}$

(C) $\begin{bmatrix} 2 & 0 & -1 \end{bmatrix}$ (D) $\{2 \ -1 \ 1/2\}$

MCQ 1.1.68 A fair coin is tossed three times in succession. If the first toss produces a head, then the probability of getting exactly two heads in three tosses is

(A) $\frac{1}{8}$ (B) $\frac{1}{2}$

(C) $\frac{3}{8}$ (D) $\frac{3}{4}$

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MCQ 1.1.69 For the function $f(x) = x^2 e^{-x}$, the maximum occurs when x is equal to

(A) 2 (B) 1

(C) 0 (D) -1

MCQ 1.1.70 For the scalar field $u = \frac{x^2}{2} + \frac{y^2}{3}$, magnitude of the gradient at the point (1, 3) is

(A) $\sqrt{\frac{13}{9}}$ (B) $\sqrt{\frac{9}{2}}$

(C) $\sqrt{5}$ (D) $\frac{9}{2}$

MCQ 1.1.71 For the equation $x''(t) + 3x'(t) + 2x(t) = 5$,the solution $x(t)$ approaches which of the following values as t " 3 ?

(A) 0 (B) $\frac{5}{2}$

(C) 5 (D) 10

****

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SOLUTION

SOL 1.1.1 Option (B) is correct.

Given, the field vector

$$\vec{F} = y^2 x\vec{a}_x - yz\vec{a}_y - x^2\vec{a}_z$$

For the line segment along x-axis, we have

$$d\vec{l} = dx\vec{a}_x$$

So, $$\vec{F} \cdot d\vec{l} = (y^2 x)(dx)$$

Since, on x-axis $y = 0$ so,

$$\vec{F} \cdot d\vec{l} = 0$$

or, $$\int \vec{F} \cdot d\vec{l} = 0$$

SOL 1.1.2 Option (D) is correct.

Given the equations in matrix form as

$$\begin{bmatrix} 2 & -2 \\ 1 & -1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

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So, it is a homogenous set of linear equation. It has either a trivial solution $(x_1 = x_2 = 0)$ or an infinite no. of solution. Since, for the matrix

$$A = \begin{bmatrix} 2 & -2 \\ 1 & -1 \end{bmatrix}$$

we have the determinant

$$|A| = 0$$

Hence, it will have multiple solutions

SOL 1.1.3 Option (B) is correct.

We know that

$$i = e^{i\pi/2} \qquad \text{(In phasor form)}$$

or, $$-i = e^{-i\pi/2}$$

So, $$\sqrt{-i} = \pm(e^{-i\pi/2})^{1/2} = \pm\, e^{-i\pi/4}$$

$$= \pm\left[\cos\left(\frac{\pi}{4}\right) - i\sin\left(\frac{\pi}{4}\right)\right]$$

$$= \cos\left(\frac{\pi}{4}\right) - i\sin\left(\frac{\pi}{4}\right)\ ;\ -\cos\left(\frac{\pi}{4}\right) + i\sin\left(\frac{\pi}{4}\right)$$

$$= \frac{1}{\sqrt{2}} - \frac{i}{\sqrt{2}}\ ;\ -1 + \frac{i}{\sqrt{2}}$$

This is equivalent to the given option (B) only.

SOL 1.1.4 Option (D) is correct.

Given the scalar field

$$V = 2x^2y + 3y^2z + 4z^2x$$

Its gradient is given by

$$\nabla V = (4xy + 4z^2)\vec{a}_x + (2x^2 + 6yz)\vec{a}_y + (3y^2 + 8zx)\vec{a}_z$$

So, the curl of the gradient is obtained as

$$\nabla \times (\nabla v) = \begin{vmatrix} \vec{a}_x & \vec{a}_y & \vec{a}_z \\ \partial/rx & \partial/ry & \partial/rz \\ 4xy + 4z^2 & 2z^2 + 6yz & 3y^2 + 8zx \end{vmatrix}$$

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$$= \vec{a}_x(6y-6y) - \vec{a}_y(8z-8z) + \vec{a}_z(4x-4x)$$
$$= 0$$

Note : From the properties of curl, we know that curl of gradient of any scalar field is always zero. So, there is no need to solve the curl and gradient.

SOL 1.1.5 Option (A) is correct.

Given, the PdF of random variable x as

$$f(x) = e^{-x} \qquad 0 < x < \infty$$

So,

$$P(x>1) = \int_1^{\infty} e^{-x}\,dx$$
$$= \left[\frac{e^{-x}}{-1}\right]_1^{\infty}$$
$$= e^{-1}$$
$$= 0.368$$

SOL 1.1.6 Option (C) is correct.

Given, the equation

$$f(x) = x^3 + 2x - 1 = 0$$

as initial condition is $x_0 = 1.2$

so, from $N-R$ method we obtain

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

here,

$$x_0 = 1.2$$
$$f(x_0) = (1.2^3) + 2(1.2) - 1 = 3.128$$

Also, $f'(x) = 3x^2 + 2$

So, $f'(x_0) = 3(1.2)^2 + 2 = 6.32$

Hence, 1st iterative value is

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$$
$$= 1.2 - \frac{3.128}{6.32}$$
$$= 0.705$$

SOL 1.1.7 Option (B) is correct.

Given the function

$$y = f(x) = 5x^2 + 10x \text{ in the internal } x = (1,2)$$

Since, function y is continuous in the interval $(1,2)$ as well as its is differentiable at each point so, from Lagranges mean value theorem there exist at least a point where

$$f'(c) = \frac{f(b) - f(a)}{b-a}$$

Here, we have

$$a = 1\ ,\ b = 2$$

So, for $x = a = 1$, we obtain

$$y = f(a) = f(1) = 5(1)^2 + 10(1) = 15$$

and for $x = b = 2$

$$y = f(b) = f(2) = 5(2)^2 + 10(2) = 40$$

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Therefore,

$$f'(c) = \frac{40-15}{2-1} = 25$$

SOL 1.1.8 Option (A) is correct.

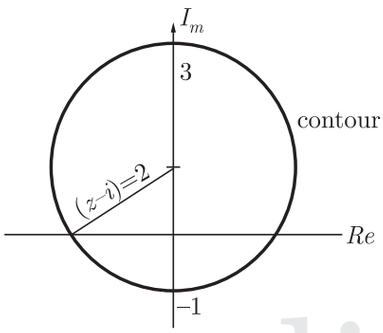
Given the contour integral

$$\oint \frac{z^2-4}{z^2+4} dz$$

It has two poles given as

$$z = \pm 2i$$

Now, the contour is defined by circle $|z-i| = 2$ which is shown in the figure below



So, it can be observed that the given contour enclosed $z = 2i$ while $z = -2i$ is out of the contour. So, we obtain the residue at $z = 2i$ only as

$$\text{residue} = \left.\frac{z^2-4}{z+2i}\right|_{z=2i}$$

$$= \frac{(2i)^2-4}{2i+2i} = \frac{-8}{4i} = 2i$$

Hence, contour integral is given as

$$\oint \frac{z^2-4}{z^2+4} dz = 2\pi i \text{ (sum of residues)}$$

$$= 2\pi i(2i)$$

$$= -4\pi$$

SOL 1.1.9 Option (D) is correct.

We know that the characteristic equation is given by

$$[A][X] = \lambda[X]$$

where $[A]$ is the matrix as λ is the scalar which gives eigen values. Now, we consider the matrix

$$[A] = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \qquad (2 \times 2 \text{ matrix})$$

For eigen value -1 as eigen vector is $\begin{bmatrix} 1 \\ -1 \end{bmatrix}$, so, we have

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} 1 \\ -1 \end{bmatrix} = -1\begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

or,
$$a - b = -1 \quad \text{....(1)}$$
$$c - d = 1 \quad \text{....(2)}$$

Similarly, for eigen value -2 with eigen vector $\begin{bmatrix} 1 \\ -2 \end{bmatrix}$, we obtain

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} 1 \\ -2 \end{bmatrix} = -2\begin{bmatrix} 1 \\ -2 \end{bmatrix}$$

or,
$$a - 2b = -2 \quad \text{....(3)}$$
$$c - 2d = 4 \quad \text{....(4)}$$

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Solving Eqs. (1) and (3), we obtain

$$a = 0, b = 1$$

and solving Eqs. (2) and (4), we obtain

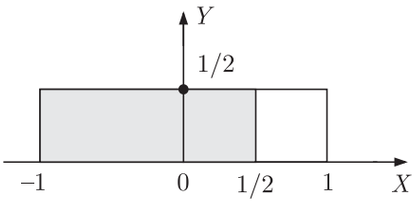
$$c = -2, d = 3$$

Thus, the required matrix is

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$$

SOL 1.1.10 Option (B) is correct.

Probability density function of uniformly distributed variables X and Y is shown as



$$P\left\{[\max(x,y)] < \frac{1}{2}\right\}$$

Since X and Y are independent.

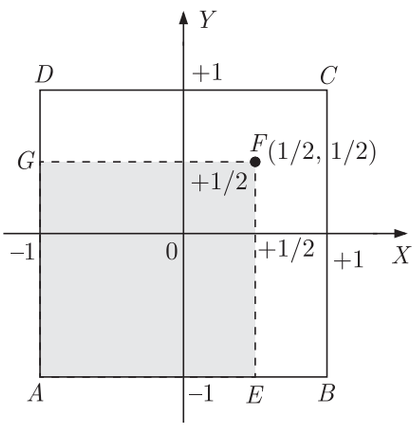
$$P\left\{[\max(x,y)] < \frac{1}{2}\right\} = P\left(X < \frac{1}{2}\right) P\left(Y < \frac{1}{2}\right)$$

$$P\left(X < \frac{1}{2}\right) = \text{shaded area} = \frac{3}{4}$$

Similarly for Y: $P\left(Y < \frac{1}{2}\right) = \frac{3}{4}$

So $P\left\{[\max(x,y)] < \frac{1}{2}\right\} = \frac{3}{4} \times \frac{3}{4} = \frac{9}{16}$

Alternate method:



From the given data since random variables X and Y lies in the interval $[-1,1]$ as from the figure X, Y lies in the region of the square $ABCD$.

Probability for $\max[X, Y] < 1/2$: The points for $\max[X, Y] < 1/2$ will be inside the region of square $AEFG$.

So, $$P\left\{\max[X, Y] < \frac{1}{2}\right\} = \frac{\text{Area of } \square AEFG}{\text{Area of square } ABCD}$$

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$$= \frac{\frac{3}{2} \times \frac{3}{2}}{2 \times 2} = \frac{9}{16}$$

SOL 1.1.11 Option (A) is correct.

$$x = \sqrt{-1} = i = \cos\frac{\pi}{2} + i\sin\frac{\pi}{2}$$

So, $x = e^{i\frac{\pi}{2}}$

$$x^x = \left(e^{i\frac{\pi}{2}}\right)^x \Rightarrow \left(e^{i\frac{\pi}{2}}\right)^i = e^{-\frac{\pi}{2}}$$

SOL 1.1.12 Option (C) is correct.

$$f(z) = \frac{1}{z+1} - \frac{2}{z+3}$$

$\frac{1}{2\pi j}\oint_C f(z)\,dz$ = sum of the residues of the poles which lie inside the given closed region.

$C \Rightarrow |z+1| = 1$

Only pole $z = -1$ inside the circle, so residue at $z = -1$ is.

$$f(z) = \frac{-z+1}{(z+1)(z+3)} = \lim_{z\to -1}\frac{(z+1)(-z+1)}{(z+1)(z+3)} = \frac{2}{2} = 1$$

So $\frac{1}{2\pi j}\oint_C f(z)\,dz = 1$

SOL 1.1.13 Option (D) is correct.

$$t\frac{dx}{dt} + x = t$$

$$\frac{dx}{dt} + \frac{x}{t} = 1$$

$$\frac{dx}{dt} + Px = Q \text{ (General form)}$$

Integrating factor, $IF = e^{\int P dt} = e^{\int \frac{1}{t}dt} = e^{\ln t} = t$

Solution has the form

$$x \times IF = \int (Q \times IF)dt + C$$

$$x \times t = \int (1)(t)\,dt + C$$

$$xt = \frac{t^2}{2} + C$$

Taking the initial condition

$$x(1) = 0.5$$

$$0.5 = \frac{1}{2} + C$$

$$C = 0$$

So, $xt = \frac{t^2}{2} \Rightarrow x = \frac{t}{2}$

SOL 1.1.14 Option (B) is correct.

Characteristic equation.

$$|A - \lambda I| = 0$$

$$\begin{vmatrix} -5-\lambda & -3 \\ 2 & -\lambda \end{vmatrix} = 0$$

$$5\lambda + \lambda^2 + 6 = 0$$

$$\lambda^2 + 5\lambda + 6 = 0$$

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Since characteristic equation satisfies its own matrix, so

$$A^2 + 5A + 6 = 0 \Rightarrow A^2 = -5A - 6I$$

Multiplying with A

$$A^3 + 5A^2 + 6A = 0$$
$$A^3 + 5(-5A - 6I) + 6A = 0$$
$$A^3 = 19A + 30I$$

SOL 1.1.15 Option (B) is correct.

$$f(x) = x^3 - 9x^2 + 24x + 5$$
$$\frac{df(x)}{dx} = 3x^2 - 18x + 24 = 0$$
$$\Rightarrow \quad \frac{df(x)}{dx} = x^2 - 6x + 8 = 0$$

$x = 4,\ x = 2$

$$\frac{d^2 f(x)}{dx^2} = 6x - 18$$

For $x = 2$, $\dfrac{d^2 f(x)}{dx^2} = 12 - 18 = -6 < 0$

So at $x = 2$, $f(x)$ will be maximum

$$f(x)\big|_{\max} = (2)^3 - 9(2)^2 + 24(2) + 5$$
$$= 8 - 36 + 48 + 5 = 25$$

SOL 1.1.16 Option (C) is correct.

Probability of appearing a head is 1/2. If the number of required tosses is odd, we have following sequence of events.

$$H,\ TTH,\ TTTTH, \ldots\ldots\ldots$$

Probability

$$P = \frac{1}{2} + \left(\frac{1}{2}\right)^3 + \left(\frac{1}{2}\right)^5 + \ldots\ldots$$

$$P = \frac{\frac{1}{2}}{1 - \frac{1}{4}} = \frac{2}{3}$$

SOL 1.1.17 Option (A) is correct.

Divergence of A in spherical coordinates is given as

$$\nabla \cdot A = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 A_r) = \frac{1}{r^2}\frac{\partial}{\partial r}(kr^{n+2})$$
$$= \frac{k}{r^2}(n+2)r^{n+1}$$
$$= k(n+2)r^{n-1} = 0 \quad \text{(given)}$$
$$n + 2 = 0$$
$$n = -2$$

SOL 1.1.18 Option (D) is correct.

$$\frac{d^2 y(t)}{dt^2} + \frac{2dy(t)}{dt} + y(t) = \delta(t)$$

By taking Laplace transform with initial conditions

$$\left[s^2 Y(s) - sy(0) - \frac{dy}{dt}\bigg|_{t=0}\right] + 2[sy(s) - y(0)] + Y(s) = 1$$

$$\Rightarrow \quad [s^2 Y(s) + 2s - 0] + 2[sY(s) + 2] + Y(s) = 1$$

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$$Y(s)[s^2+2s+1] = 1-2s-4$$

$$Y(s) = \frac{-2s-3}{s^2+2s+1}$$

We know If, $y(t) \xleftrightarrow{\mathcal{L}} Y(s)$

then, $\frac{dy(t)}{dt} \xleftrightarrow{\mathcal{L}} sY(s) - y(0)$

So,
$$sY(s) - y(0) = \frac{(-2s-3)s}{(s^2+2s+1)} + 2$$
$$= \frac{-2s^2-3s+2s^2+4s+2}{(s^2+2s+1)}$$
$$sY(s) - y(0) = \frac{s+2}{(s+1)^2} = \frac{s+1}{(s+1)^2} + \frac{1}{(s+1)^2}$$
$$= \frac{1}{s+1} + \frac{1}{(s+1)^2}$$

By taking inverse Laplace transform

$$\frac{dy(t)}{dt} = e^{-t}u(t) + te^{-t}u(t)$$

At $t = 0^+$, $\left.\frac{dy}{dt}\right|_{t=0^+} = e^0 + 0 = 1$

SOL 1.1.19 Option (D) is correct.

$$x^3 + x^2 + x + 1 = 0$$
$$x^2(x+1) + (x-1) = 0$$
$$(x+1)(x^2+1) = 0$$

or $x+1 = 0 \Rightarrow x = -1$

and $x^2+1 = 0 \Rightarrow x = -j, j$

$$x = -1, -j, j$$

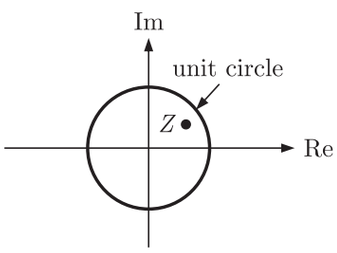
SOL 1.1.20 Option (A) is correct.

$$\frac{dy}{dx} = e^{-3x}$$
$$dy = e^{-3x}dx$$

by integrating, we get

$y = -\frac{1}{3}e^{-3x} + K$, where K is constant.

SOL 1.1.21 Option (D) is correct.



$\overline{Z}$ is $|Z| = 0$ where θ is around 45° or so.

Thus $\overline{Z} = |Z| \angle 45^\circ$ where $|Z| < 1$

$$\overline{Y} = \frac{1}{Z} = \frac{1}{|Z| \angle 45^\circ} = \frac{1}{|Z|} \angle -45^\circ$$

$|\overline{Y}| > 1 [\because |Z| < 1]$

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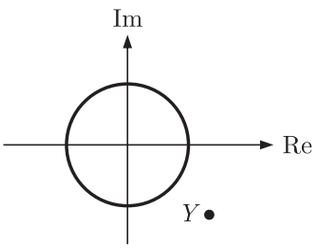


So Y will be out of unity circle.

SOL 1.1.22 Option (B) is correct.

$$f_1 = 10x_2 \sin x_1 - 0.8$$
$$f_2 = 10x_2^2 - 10x_2 \cos x_1 - 0.6$$

Jacobian matrix is given by

$$J = \begin{bmatrix} \frac{\partial f_1}{\partial x_1} & \frac{\partial f_1}{\partial x_2} \\ \frac{\partial f_2}{\partial x_1} & \frac{\partial f_2}{\partial x_2} \end{bmatrix} = \begin{bmatrix} 10x_2 \cos x_1 & 10 \sin x_1 \\ 10x_2 \sin x_1 & 20x_2 - 10 \cos x_1 \end{bmatrix}$$

For $x_1 = 0, x_2 = 1$, $J = \begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix}$

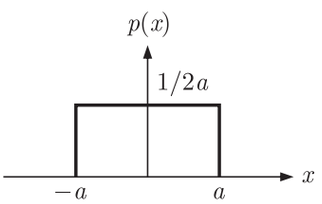
SOL 1.1.23 Option (C) is correct.

$$f(x) = 2x - x^2 + 3$$
$$f'(x) = 2 - 2x = 0$$
$$x = 1$$
$$f''(x) = -2$$

$f''(x)$ is negative for $x = 1$, so the function has a maxima at $x = 1$.

SOL 1.1.24 Option (A) is correct.

Let a signal $p(x)$ is uniformly distributed between limits $-a$ to $+a$.



Variance $\sigma_p = \int_{-a}^{a} x^2 p(x)\,dx = \int_{-a}^{a} x^2 \cdot \frac{1}{2a} dx$

$$= \frac{1}{2a}\left[\frac{x^3}{3}\right]_{-a}^{a} = \frac{2a^3}{6} = \frac{a^2}{3}$$

It means square value is equal to its variance

$$p_{\text{rms}}^2 = \sigma_p = \frac{a^2}{3}$$

$$p_{\text{rms}} = \frac{a}{\sqrt{3}}$$

SOL 1.1.25 Option (D) is correct.

We know that matrix A is equal to product of lower triangular matrix L and upper triangular matrix U.

$$A = [L][U]$$

only option (D) satisfies the above relation.

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SOL 1.1.26 Option (B) is correct.

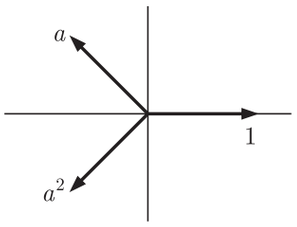
Let the given two vectors are

$$X_1 = [1,1,1]$$
$$X_2 = [1,a,a^2]$$

Dot product of the vectors

$$\mathbf{X}_1 \cdot \mathbf{X}_2 = X_1 X_2^T = \begin{bmatrix}1 & 1 & 1\end{bmatrix}\begin{bmatrix}1\\ a\\ a^2\end{bmatrix} = 1 + a + a^2$$

Where $a = -\frac{1}{2} + j\frac{\sqrt{3}}{2} = 1\angle -2\pi/3$



so,

$1 + a + a^2 = 0$ X_1, X_2 are orthogonal

Note: We can see that X_1, X_2 are not orthonormal as their magnitude is $\neq 1$

SOL 1.1.27 Option (B) is correct.

$$P = \int_0^1 xe^x dx$$
$$= \left[x\int e^x dx\right]_0^1 - \int_0^1 \left[\frac{d}{dx}(x)\int e^x dx\right]dx$$
$$= \left[xe^x\right]_0^1 - \int_0^1 (1)\,e^x dx = (e^1 - 0) - \left[e^x\right]_0^1$$
$$= e^1 - [e^1 - e^0] = 1$$

SOL 1.1.28 Option (A) is correct.

Radial vector $\vec{\mathbf{r}} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$

Divergence $= \nabla \cdot \vec{\mathbf{r}}$

$$= \left(\frac{\partial}{\partial x}\hat{\mathbf{i}} + \frac{\partial}{\partial y}\hat{\mathbf{j}} + \frac{\partial}{\partial z}\hat{\mathbf{k}}\right) \cdot \left(x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}\right)$$
$$= \frac{\partial x}{\partial x} + \frac{\partial y}{\partial y} + \frac{\partial z}{\partial z} = 1 + 1 + 1 = 3$$

SOL 1.1.29 Option (C) is correct.

No of white balls $= 4$, no of red balls$= 3$

If first removed ball is white then remaining no of balls $= 6\,(3\,\text{white}, 3\,\text{red})$

we have 6 balls, one ball can be choose in ${}^6C_1$ ways, since there are three red balls so probability that the second ball is red is

$$P = \frac{{}^6C_1}{{}^3C_1} = \frac{3}{6} = \frac{1}{2}$$

SOL 1.1.30 Option (D) is correct.

Function $f(t) = \frac{\sin t}{t} = \sin ct$ has a maxima at $t = 0$ as shown below

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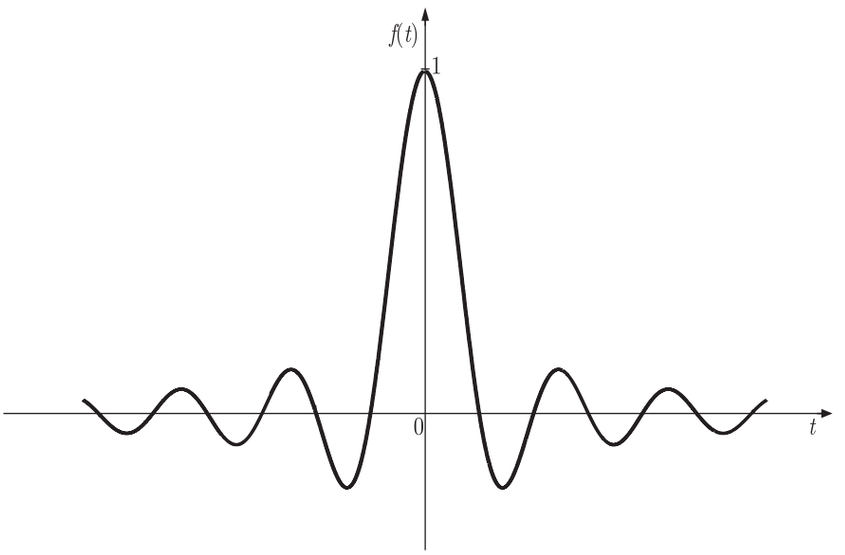

SOL 1.1.31 Option (B) is correct.

Let eigen vector

$$X = \begin{bmatrix} x_1 & x_2 & x_3 \end{bmatrix}^T$$

Eigen vector corresponding to $\lambda_1 = 1$

$$\begin{bmatrix} A & -\lambda_1 & I \end{bmatrix} X = 0$$

$$\begin{bmatrix} 0 & 1 & 0 \\ 0 & 1 & 2 \\ 0 & 0 & 2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$x_2 = 0$$

$$x_2 + 2x_3 = 0 \Rightarrow x_3 = 0 \text{ (not given in the option)}$$

Eigen vector corresponding to $\lambda_2 = 2$

$$\begin{bmatrix} A & -\lambda_2 & I \end{bmatrix} X = 0$$

$$\begin{bmatrix} -1 & 1 & 0 \\ 0 & 0 & 2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$-x_1 + x_2 = 0$$

$$2x_3 = 0 \Rightarrow x_3 = 0 \text{ (not given in options.)}$$

Eigen vector corresponding to $\lambda_3 = 3$

$$\begin{bmatrix} A & -\lambda_3 & I \end{bmatrix} X = 0$$

$$\begin{bmatrix} -2 & 1 & 0 \\ 0 & -1 & 2 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$-2x_1 + x_2 = 0$$

$$-x_2 + 2x_3 = 0$$

Put $x_1 = 1, x_2 = 2$ and $x_3 = 1$

So Eigen vector

$$X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 2 & 1 \end{bmatrix}^T$$

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SOL 1.1.32 Option (B) is correct.

$$\frac{d^2x}{dt^2} + 6\frac{dx}{dt} + 8x = 0$$

Taking Laplace transform (with initial condition) on both sides

$$s^2X(s) - sx(0) - x'(0) + 6[sX(s) - x(0)] + 8X(s) = 0$$
$$s^2X(s) - s(1) - 0 + 6[sX(s) - 1] + 8X(s) = 0$$
$$X(s)[s^2 + 6s + 8] - s - 6 = 0$$
$$X(s) = \frac{(s+6)}{(s^2+6s+8)}$$

By partial fraction

$$X(s) = \frac{2}{s+2} - \frac{1}{s+4}$$

Taking inverse Laplace transform

$$x(t) = (2e^{-2t} - e^{-4t})$$

SOL 1.1.33 Option (C) is correct.

Set of equations

$$x_1 + 2x_2 + x_3 + 4x_4 = 2 \quad .....(1)$$
$$3x_1 + 6x_2 + 3x_3 + 12x_4 = 6 \quad .....(2)$$

or $3(x_1 + 2x_2 + x_3 + 4x_4) = 3 \times 2$

Equation (2) is same as equation(1) except a constant multiplying factor of 3. So infinite (multiple) no. of non-trivial solution exists.

SOL 1.1.34 Option (C) is correct.

Let the matrix is $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$

Trace of a square matrix is sum of its diagonal entries

$$\text{Trace } A = a + d = -2$$

Determinent $ad - bc = -35$

Eigenvalue $|A - \lambda I| = 0$

$$\begin{vmatrix} a-\lambda & b \\ c & d-\lambda \end{vmatrix} = 0$$
$$(a-\lambda)(d-\lambda) - bc = 0$$
$$\lambda^2 - (a+d)\lambda + (ad - bc) = 0$$
$$\lambda^2 - (-2)\lambda + (-35) = 0$$
$$\lambda^2 + 2\lambda - 35 = 0$$
$$(\lambda - 5)(\lambda + 7) = 0$$
$$\lambda_1, \lambda_2 = 5, -7$$

SOL 1.1.35 Option (A) is correct.

Given constraints $x > y^2$ and $y > x^2$

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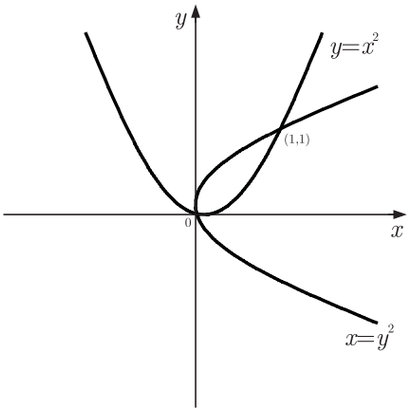

Limit of y : $y = 0$ to $y = 1$
Limit of x : $x = y^2$ to $x^2 = y \Rightarrow x = \sqrt{y}$
So volume under $f(x,y)$

$$V = \int_{y=0}^{y=1} \int_{x=y^2}^{x=\sqrt{y}} f(x,y)\, dx\, dy$$

SOL 1.1.36 Option (B) is correct.
No of events of at least two people in the room being born on same date $= {}^nC_2$
three people in the room being born on same date $= {}^nC_3$
Similarly four for people $= {}^nC_4$
Probability of the event, $0.5 \geq \dfrac{{}^nC_2 \cdot {}^nC_3 \cdot {}^nC_4 \cdots {}^nC_n}{\underline{\lfloor N}} \Rightarrow N = 7$

SOL 1.1.37 Option ( ) is correct.
Assume a Cubic polynomial with real Coefficients

$$P(x) = a_0x^3 + a_1x^3 + a_2x + a_3 \qquad a_0, a_1, a_2, a_3 \text{ are real}$$
$$P'(x) = 3a_0x^2 + 2a_1x + a_2$$
$$P''(x) = 6a_0x + 2a_1$$
$$P'''(x) = 6a_0$$
$$P^{iv}(x) = 0$$

SOL 1.1.38 Option (D) is correct.
An iterative sequence in Newton-Raphson's method is obtained by following expression

$$x_{k+1} = x_k - \frac{f(x_k)}{f'(x_k)}$$
$$f(x) = x^2 - 117$$
$$f'(x) = 2x$$

So $f(x_k) = x_k^2 - 117$
$f'(x_k) = 2x_k = 2 \times 117$

So $x_{k+1} = x_k - \dfrac{x_k^2 - 117}{2x_k} = x_k - \dfrac{1}{2}\left[x_k + \dfrac{117}{x_k}\right]$

SOL 1.1.39 Option (D) is correct.
Equation of straight line

$$y - 2 = \frac{0-2}{2-0}(x-0)$$
$$y - 2 = -x$$
$$\vec{F} \cdot \vec{dl} = [(x^2 + xy)\,\hat{a}_x + (y^2 + xy)\,\hat{a}_y]\,[dx\hat{a}_x + dy\hat{a}_y + dz\hat{a}_z]$$

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$$= (x^2 + xy)\,dx + (y^2 + xy)\,dy$$

Limit of x : 0 to 2

Limit of y : 2 to 0

$$\int \vec{F} \cdot \vec{dl} = \int_0^2 (x^2 + xy)\,dx + \int_2^0 (y^2 + xy)\,dy$$

Line $y - 2 = -x$

$$dy = -dx$$

So $$\int \vec{F} \cdot \vec{dl} = \int_0^2 [x^2 + x(2-x)]\,dx + \int_2^0 y^2 + (2-y)y\,dy$$

$$= \int_0^2 2x\,dx + \int_2^0 2y\,dy$$

$$= 2\left[\frac{x^2}{2}\right]_0^2 + 2\left[\frac{y^2}{2}\right]_2^0 = 4 - 4 = 0$$

SOL 1.1.40 Option (C) is correct.

X is uniformly distributed between 0 and 1

So probability density function

$$f_X(X) = \begin{cases} 1, & 0 < x < 1 \\ 0, & \text{otherwise} \end{cases}$$

So, $$E\{X^3\} = \int_0^1 X^3 f_X(X)\,dx = \int_0^1 X^3(1)\,dx$$

$$= \left[\frac{X^4}{4}\right]_0^1 = \frac{1}{4}$$

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SOL 1.1.41 Option (D) is correct.

According to CAYLEY-HAMILTON Theorem every non-singular square matrix satisfies its own characteristic equation.

Characteristic equation

$$a(\lambda) = |\lambda I - P| = \lambda^3 + \lambda^2 + 2\lambda + 1 = 0$$

Matrix P satisfies above equation

$$P^3 + P^2 + 2P + I = 0$$

$$I = -(P^3 + P^2 + 2P)$$

Multiply both sides by P^{-1}

$$P^{-1} = -(P^2 + P + 2I)$$

SOL 1.1.42 Option (A) is correct.

Rank of a matrix is no. of linearly independent rows and columns of the matrix.

Here Rank $\rho(Q) = 4$

So Q will have 4 linearly independent rows and flour independent columns.

SOL 1.1.43 Option (B) is correct.

Given function

$$f(x) = (x^2 - 4)^2$$

$$f'(x) = 2(x^2 - 4)2x$$

To obtain minima and maxima

$$f'(x) = 0$$

$$4x(x^2 - 4) = 0$$

$$x = 0, x^2 - 4 = 0 \Rightarrow x = \pm 2$$

So, $$x = 0, +2, -2$$

$$f''(x) = 4x(2x) + 4(x^2 - 4) = 12x^2 - 16$$

For $x = 0, f''(0) = 12(0)^2 - 16 = -16 < 0$ (Maxima)

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$x = +2, f''(2) = 12(2)^2 - 16 = 32 > 0$ (Minima)
$x = -2, f''(-2) = 12(-2)^2 - 16 = 32 > 0$ (Minima)

So $f(x)$ has only two minima

SOL 1.1.44 Option (A) is correct.

An iterative sequence in Newton-Raphson method can obtain by following expression

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

We have to calculate x_1, so $n = 0$

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}, \text{ Given } x_0 = -1$$
$$f(x_0) = e^{x_0} - 1 = e^{-1} - 1 = -0.63212$$
$$f'(x_0) = e^{x_0} = e^{-1} = 0.36787$$

So,
$$x_1 = -1 - \frac{(-0.63212)}{(0.36787)}$$
$$= -1 + 1.71832 = 0.71832$$

SOL 1.1.45 Option (D) is correct.

$$A' = (A^T A)^{-1} A^T = A^{-1}(A^T)^{-1} A^T = A^{-1} I$$

Put $A' = A^{-1} I$ in all option.

option (A)
$$AA'A = A$$
$$AA^{-1}A = A$$
$$A = A \quad \text{(true)}$$

option (B)
$$(AA')^2 = I$$
$$(AA^{-1}I)^2 = I$$
$$(I)^2 = I \quad \text{(true)}$$

option (C)
$$A'A = I$$
$$A^{-1}IA = I$$
$$I = I \quad \text{(true)}$$

option (D)
$$AA'A = A'$$
$$AA^{-1}IA = A \neq A' \quad \text{(false)}$$

SOL 1.1.46 Option (C) is correct.

$$\frac{dx}{dt} = e^{-2t} u(t)$$
$$x = \int e^{-2t} u(t)\, dt = \int_0^1 e^{-2t}\, dt$$
$$= \int_0^1 f(t)\, dt,$$
$$t = .01 \text{ s}$$

From trapezoid rule

$$\int_{t_0}^{t_0 + nh} f(t)\, dt = \frac{h}{2}[f(0) + f(.01)]$$
$$\int_0^1 f(t)\, dt = \frac{.01}{2}[e^0 + e^{-.02}],\ h = .01$$

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$$= .0099$$

SOL 1.1.47 Option (B) is correct.

P is an orthogonal matrix So $PP^T = I$

Let assume $$P = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$$

$$P\vec{X} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_1 & x_2 \end{bmatrix}^T$$

$$= \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} x_1\cos\theta - x_2\sin\theta \\ x_1\sin\theta + x_2\cos\theta \end{bmatrix}$$

$$\left|\left| P\vec{X} \right|\right| = \sqrt{(x_1\cos\theta - x_2\sin\theta)^2 + (x_1\sin\theta + x_2\cos\theta)^2}$$

$$= \sqrt{x_1^2 + x_2^2}$$

$$\left|\left| P\vec{X} \right|\right| = \left|\left| \vec{X} \right|\right|$$

SOL 1.1.48 Option (D) is correct.

$$\mathbf{x} = \begin{bmatrix} x_1 & x_2 & \cdots & x_n \end{bmatrix}^{\mathrm{T}}$$

$$V = \mathbf{x}\mathbf{x}^{\mathrm{T}}$$

$$= \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$$

So rank of V is n.

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SOL 1.1.49 Option ( ) is correct.

SOL 1.1.50 Option (A) is correct.

Given $$\oint_C \frac{dz}{1+z^2} = \oint_C \frac{dz}{(z+i)(z-i)}$$

Contour $$\left| z - \frac{i}{2} \right| = 1$$

P(0, 1) lies inside the circle $\left| z - \frac{i}{2} \right| = 1$ and $P(0,1)$ does not lie.

So by Cauchy's integral formula

$$\oint_C \frac{dz}{1+z^2} = 2\pi i \lim_{z \to i} (z-i) \frac{1}{(z+i)(z-i)}$$

$$= 2\pi i \lim_{z \to i} \frac{1}{z+i} = 2\pi i \times \frac{1}{2i} = \pi$$

SOL 1.1.51 Option ( ) is correct.

SOL 1.1.52 Option (C) is correct.

Probability of occurrence of values 1,5 and 6 on the three dice is

$$P(1,5,6) = P(1)P(5)P(6)$$

$$= \frac{1}{4} \times \frac{1}{8} \times \frac{1}{4} = \frac{1}{128}$$

In option (A)

$$P(3,4,5) = P(3)P(4)P(5)$$

$$= \frac{1}{8} \times \frac{1}{8} \times \frac{1}{8} = \frac{1}{512}$$

In option (B)

$$P(1,2,5) = P(1)P(2)P(5)$$

$$= \frac{1}{4} \times \frac{1}{8} \times \frac{1}{8} = \frac{1}{256}$$

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SOL 1.1.53 Option (D) is correct.

$$\det\begin{bmatrix} x\cdot x & x\cdot y \\ y\cdot x & y\cdot y \end{bmatrix} = (x\cdot x)(y\cdot y) - (x\cdot y)(y\cdot x)$$

$= 0$ only when x or y is zero

SOL 1.1.54 Option ( ) is correct.

SOL 1.1.55 Option (C) is correct.

For characteristic equation

$$\begin{bmatrix} -3-\lambda & 2 \\ -1 & 0-\lambda \end{bmatrix} = 0$$

or $$(-3-\lambda)(-\lambda)+2 = 0$$

$$(\lambda+1)(\lambda+2) = 0$$

According to Cayley-Hamiliton theorem

$$(A+I)(A+2I) = 0$$

SOL 1.1.56 Option (A) is correct.

According to Cayley-Hamiliton theorem

$$(A+I)(A+2I) = 0$$

or $$A^2+3A+2I = 0$$

or $$A^2 = -(3A+2I)$$

or $$A^4 = (3A+2I)^2 = (9A^2+12A+4I)$$

$$= 9(-3A-2I)+12A+4I = -15A-14I$$

$$A^8 = (-15A-14I)^2 = 225A^2+420A+196$$

$$= 225(-3A-2I)+420A+196I = -255A-254I$$

$$A^9 = -255A^2-254A$$

$$= -255(-3A-2I)-254A = 511A+510I$$

SOL 1.1.57 Option (D) is correct.

Volume of the cone

$$V = \int_0^H \pi R^2\left(1-\frac{h}{H}\right)^2 dh$$

Solving the above integral

$$V = \frac{1}{3}\pi R^2 H$$

Solve all integrals given in option only for option (D)

$$\int_0^R 2\pi r H\left(1-\frac{r}{R}\right)^2 dr = \frac{1}{3}\pi R^2 H$$

SOL 1.1.58 Option ( ) is correct.

SOL 1.1.59 Option (C) is correct.

By throwing dice twice $6\times 6 = 36$ possibilities will occur. Out of these sample space consist of sum 4, 8 and 12 because $r/4$ is an integer. This can occur in following way :

(1, 3), (2, 2), (2, 6), (3, 1), (3, 5), (4, 4), (5, 3), (6, 2) and (6, 6)

Sample Space $= 9$

Favourable space is coming out of 8 $= 5$

Probability of coming out 8 $= \frac{5}{9}$

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SOL 1.1.60 Option ( ) is correct.

SOL 1.1.61 Option ( ) is correct.

SOL 1.1.62 Option (A) is correct.

Matrix equation $PX = q$ has a unique solution if

$$\rho(P) = \rho(r)$$

Where $\rho(P) \rightarrow$ rank of matrix P

$\rho(r) \rightarrow$ rank of augmented matrix $[P]$

$$r = [P \ : \ q]$$

SOL 1.1.63 Option (D) is correct.

for two random events conditional probability is given by

$$\text{probability}(P \cap Q) = \text{probability}(P)\,\text{probability}(Q)$$

$$\text{probability}(Q) = \frac{\text{probability}(P \cap Q)}{\text{probability}(P)} \leq 1$$

so $\text{probability}(P \cap Q) \leq \text{probability}(P)$

SOL 1.1.64 Option (C) is correct.

$$S = \int_1^{\infty} x^{-3} dx = \left[\frac{x^{-2}}{-2}\right]_1^{\infty} = \frac{1}{2}$$

SOL 1.1.65 Option (A) is correct.

We have $\dot{x}(t) = -3x(t)$

or $\dot{x}(t) + 3x(t) = 0$

A.E. $D + 3 = 0$

Thus solution is $x(t) = C_1 e^{-3t}$

From $x(0) = x_0$ we get $C_1 = x_0$

Thus $x(t) = x_0 e^{-3t}$

SOL 1.1.66 Option (D) is correct.

For eigen value $\lambda = -2$

$$\begin{bmatrix} 3-(-2) & -2 & 2 \\ 0 & -2-(-2) & 1 \\ 0 & 0 & 1-(-2) \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 5 & -2 & 2 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$5x_1 - 2x_2 + x_3 = 0$$

SOL 1.1.67 Option (B) is correct.

$$C_{11} = 2 - (-3) = 5$$

$$C_{21} = -(0 - (-3)) = -3$$

$$C_{31} = (-(-1)) = 1$$

$$|R| = (1)C_{11} + 2C_{21} + 2C_{31} = 5 - 6 + 2 = 1$$

SOL 1.1.68 Option (B) is correct.

If the toss produces head, then for exactly two head in three tosses three tosses there must produce one head in next two tosses. The probability of one head in two tosses will be 1/2.

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SOL 1.1.69 Option (A) is correct.

We have $f(x) = x^2 e^{-x}$

or $f'(x) = 2xe^{-x} - x^2 e^{-x}$

$= xe^{-x}(2-x)$

$f''(x) = (x^2 - 4x + 2)e^{-x}$

Now for maxima and minima, $f'(x) = 0$

$xe^{-x}(2-x) = 0$

or $x = 0, 2$

at $x = 0$ $f''(0) = 1\,(+\text{ve})$

at $x = 2$ $f''(2) = -2e^{-2}(-\text{ve})$

Now $f''(0) = 1$ and $f''(2) = -2e^{-2} < 0$. Thus $x = 2$ is point of maxima

SOL 1.1.70 Option (C) is correct.

$$\nabla u = \left(\hat{\mathrm{i}}\frac{\partial}{\partial x} + \hat{\mathrm{j}}\frac{\partial}{\partial y}\right)u = \hat{\mathrm{i}}\frac{\partial u}{\partial x} + \hat{\mathrm{j}}\frac{\partial u}{\partial y} = x\hat{\mathrm{i}} + \frac{2}{3}y\hat{\mathrm{j}}$$

At (1, 3) magnitude is $|\nabla u| = \sqrt{x^2 + \left(\frac{2}{3}y\right)^2} = \sqrt{1+4} = \sqrt{5}$

SOL 1.1.71 Option (B) is correct.

$$\frac{d^2x}{dt^2} + \frac{3dx}{dt} + 2x(t) = 5$$

Taking Laplace transform on both sides of above equation.

$$s^2X(s) + 3sX(s) + 2X(s) = \frac{5}{s}$$

$$X(s) = \frac{5}{s(s^2 + 3s + 2)}$$

From final value theorem

$$\lim_{t\to\infty} x(t) = \lim_{s\to 0} X(s) = \lim_{s\to 0} s\frac{5}{s(s^2+3s+2)} = \frac{5}{2}$$

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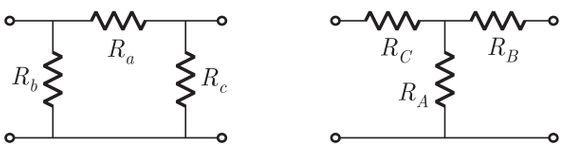
2

ELECTRICAL CIRCUITS & FIELDS

YEAR 2013 ONE MARK

MCQ 1.2.1 Consider a delta connection of resistors and its equivalent star connection as shown below. If all elements of the delta connection are scaled by a factor k, $k > 0$, the elements of the corresponding star equivalent will be scaled by a factor of



(A) k^2 (B) k

(C) $1/k$ (D) $\sqrt{k}$

MCQ 1.2.2 The flux density at a point in space is given by $\vec{B} = 4x\vec{a}_x + 2ky\vec{a}_y + 8\vec{a}_z$ Wb/m^2. The value of constant k must be equal to

(A) -2 (B) -0.5

(C) $+0.5$ (D) $+2$

MCQ 1.2.3 A single-phase load is supplied by a single-phase voltage source. If the current flowing from the load to the source is $10\angle -150^\circ$A and if the voltage at the load terminal is $100\angle 60^\circ$V, then the

(A) load absorbs real power and delivers reactive power

(B) load absorbs real power and absorbs reactive power

(C) load delivers real power and delivers reactive power

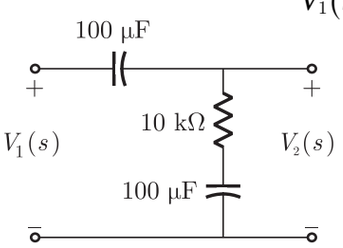
(D) load delivers real power and absorbs reactive power

MCQ 1.2.4 A source $v_s(t) = V\cos 100\pi t$ has an internal impedance of $(4 + j3)\Omega$. If a purely resistive load connected to this source has to extract the maximum power out of the source, its value in Ω should be

(A) 3 (B) 4

(C) 5 (D) 7

MCQ 1.2.5 The transfer function $\dfrac{V_2(s)}{V_1(s)}$ of the circuit shown below is



(A) $\dfrac{0.5s + 1}{s + 1}$ (B) $\dfrac{3s + 6}{s + 2}$

(C) $\frac{s+2}{s+1}$ (D) $\frac{s+1}{s+2}$

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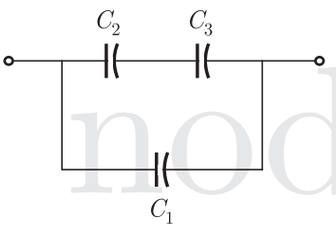
MCQ 1.2.6 A dielectric slab with 500 mm × 500 mm cross-section is 0.4 m long. The slab is subjected to a uniform electric field of $\vec{E} = 6\vec{a}_x + 8\vec{a}_y$ kV/mm. The relative permittivity of the dielectric material is equal to 2. The value of constant ε_0 is 8.85×10^{-12} F/m. The energy stored in the dielectric in Joules is

(A) 8.85×10^{-11} (B) 8.85×10^{-5}

(C) 88.5 (D) 885

MCQ 1.2.7 Three capacitors C_1, C_2 and C_3 whose values are 10 μF, 5 μF, and 2 μF respectively, have breakdown voltages of 10 V, 5 V and 2 V respectively. For the interconnection shown below, the maximum safe voltage in Volts that can be applied across the combination, and the corresponding total charge in μC stored in the effective capacitance across the terminals are respectively,



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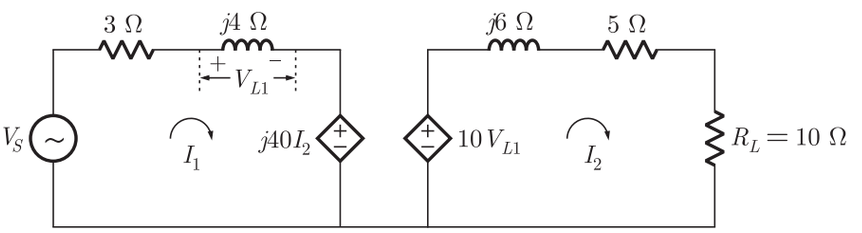
(A) 2.8 and 36 (B) 7 and 119

(C) 2.8 and 32 (D) 7 and 80

MCQ 1.2.8 In the circuit shown below, if the source voltage $V_S = 100\angle 53.13^\circ$ V then the Thevenin's equivalent voltage in Volts as seen by the load resistance R_L is



(A) $100\angle 90^\circ$ (B) $800\angle 0^\circ$

(C) $800\angle 90^\circ$ (D) $100\angle 60^\circ$

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MCQ 1.2.9 In the circuit shown below, the current through the inductor is

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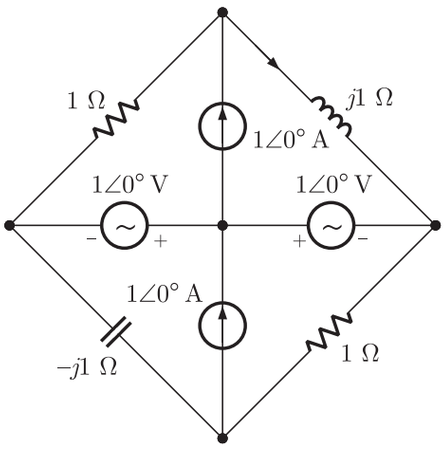
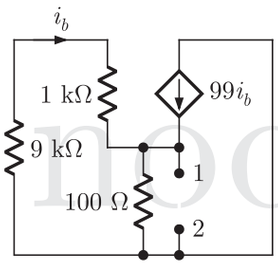


(A) $\frac{2}{1+j}$ A (B) $\frac{-1}{1+j}$ A

(C) $\frac{1}{1+j}$ A (D) 0 A

MCQ 1.2.10 The impedance looking into nodes 1 and 2 in the given circuit is



(A) 50 Ω (B) 100 Ω

(C) 5 kΩ (D) 10.1 kΩ

MCQ 1.2.11 A system with transfer function $G(s) = \frac{(s^2+9)(s+2)}{(s+1)(s+3)(s+4)}$ is excited by $\sin(\omega t)$. The steady-state output of the system is zero at

(A) $\omega = 1$ rad/s (B) $\omega = 2$ rad/s

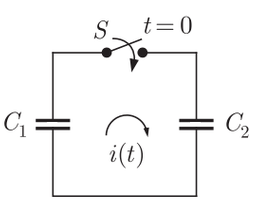
(C) $\omega = 3$ rad/s (D) $\omega = 4$ rad/s

MCQ 1.2.12 The average power delivered to an impedance $(4 - j3)\,\Omega$ by a current $5\cos(100\pi t + 100)$ A is

(A) 44.2 W (B) 50 W

(C) 62.5 W (D) 125 W

MCQ 1.2.13 In the following figure, C_1 and C_2 are ideal capacitors. C_1 has been charged to 12 V before the ideal switch S is closed at $t = 0$. The current $i(t)$ for all t is



(A) zero (B) a step function

(C) an exponentially decaying function (D) an impulse function

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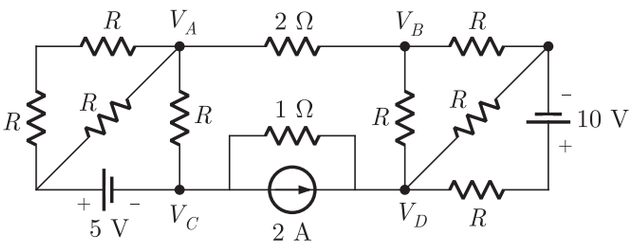
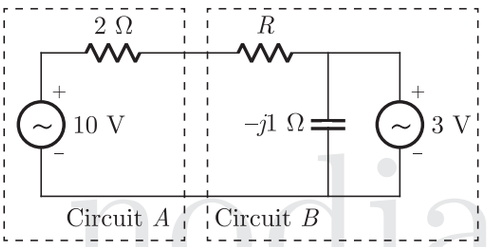
MCQ 1.2.14 If $V_A - V_B = 6$ V then $V_C - V_D$ is



(A) -5 V (B) 2 V

(C) 3 V (D) 6 V

MCQ 1.2.15 Assuming both the voltage sources are in phase, the value of R for which maximum power is transferred from circuit A to circuit B is



(A) 0.8 Ω (B) 1.4 Ω

(C) 2 Ω (D) 2.8 Ω

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Common Data for Questions 16 and 17 :

With 10 V dc connected at port A in the linear nonreciprocal two-port network shown below, the following were observed :

(i) 1 Ω connected at port B draws a current of 3 A

(ii) 2.5 Ω connected at port B draws a current of 2 A

MCQ 1.2.16 With 10 V dc connected at port A, the current drawn by 7 Ω connected at port B is

(A) 3/7 A (B) 5/7 A

(C) 1 A (D) 9/7 A

MCQ 1.2.17 For the same network, with 6 V dc connected at port A, 1 Ω connected at port B draws 7/3 A. If 8 V dc is connected to port A, the open circuit voltage at port B is

(A) 6 V (B) 7 V

(C) 8 V (D) 9 V

Statement for Linked Answer Questions 18 and 19 :

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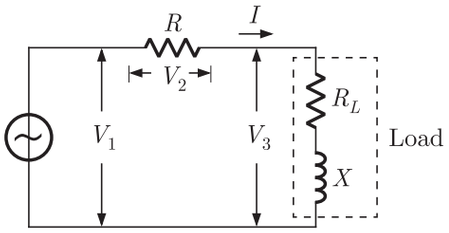
In the circuit shown, the three voltmeter readings are $V_1 = 220\,\text{V}$, $V_2 = 122\,\text{V}$, $V_3 = 136\,\text{V}$.



MCQ 1.2.18 The power factor of the load is

(A) 0.45 (B) 0.50

(C) 0.55 (D) 0.60

MCQ 1.2.19 If $R_L = 5\,\Omega$, the approximate power consumption in the load is

(A) 700 W (B) 750 W

(C) 800 W (D) 850 W

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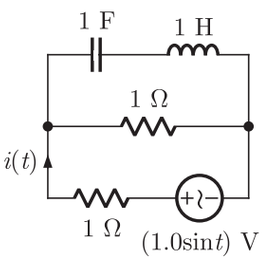
MCQ 1.2.20 The r.m.s value of the current $i(t)$ in the circuit shown below is

(A) $\frac{1}{2}$ A (B) $\frac{1}{\sqrt{2}}$ A

(C) 1 A (D) $\sqrt{2}$ A

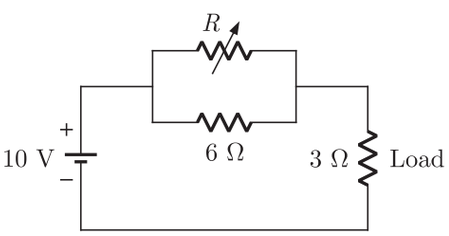


MCQ 1.2.21 The voltage applied to a circuit is $100\sqrt{2}\cos(100\pi t)$ volts and the circuit draws a current of $10\sqrt{2}\sin(100\pi t + \pi/4)$ amperes. Taking the voltage as the reference phasor, the phasor representation of the current in amperes is

(A) $10\sqrt{2}\angle -\pi/4$ (B) $10\angle -\pi/4$

(C) $10\angle +\pi/4$ (D) $10\sqrt{2}\angle +\pi/4$

MCQ 1.2.22 In the circuit given below, the value of R required for the transfer of maximum power to the load having a resistance of $3\,\Omega$ is



(A) zero (B) $3\,\Omega$

(C) $6\,\Omega$ (D) infinity

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MCQ 1.2.23 A lossy capacitor C_x, rated for operation at 5 kV, 50 Hz is represented by an equivalent circuit with an ideal capacitor C_p in parallel with a resistor R_p. The value C_p is found to be 0.102 μF and value of $R_p = 1.25\,\text{M}\Omega$. Then the power loss and $\tan\delta$ of the lossy capacitor operating at the rated voltage, respectively, are

(A) 10 W and 0.0002 (B) 10 W and 0.0025

(C) 20 W and 0.025 (D) 20 W and 0.04

MCQ 1.2.24 A capacitor is made with a polymeric dielectric having an ε_r of 2.26 and a dielectric breakdown strength of 50 kV/cm. The permittivity of free space is 8.85 pF/m. If the rectangular plates of the capacitor have a width of 20 cm and a length of 40 cm, then the maximum electric charge in the capacitor is

(A) 2 μC (B) 4 μC

(C) 8 μC (D) 10 μC

Common Data questions: 25 & 26

The input voltage given to a converter is $v_i = 100\sqrt{2}\sin(100\pi t)$ V

The current drawn by the converter is

$i_i = 10\sqrt{2}\sin(100\pi t - \pi/3) + 5\sqrt{2}\sin(300\pi t + \pi/4) + 2\sqrt{2}\sin(500\pi t - \pi/6)$ A

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MCQ 1.2.25 The input power factor of the converter is

(A) 0.31 (B) 0.44

(C) 0.5 (D) 0.71

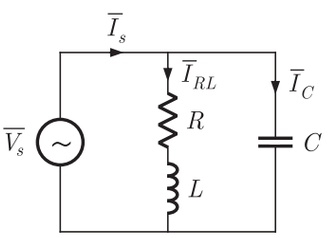
MCQ 1.2.26 The active power drawn by the converter is

(A) 181 W (B) 500 W

(C) 707 W (D) 887 W

Common Data questions: 27 & 28

An RLC circuit with relevant data is given below.



$\overline{V}_s = 1\angle 0$ V

$\overline{I}_{RL} = \sqrt{2}\angle -\pi/4$ A

MCQ 1.2.27 The power dissipated in the resistor R is

(A) 0.5 W (B) 1 W

(C) $\sqrt{2}$ W (D) 2 W

MCQ 1.2.28 The current $\overline{I_C}$ in the figure above is

(A) $-j2$ A (B) $-j\frac{1}{\sqrt{2}}$ A

(C) $+j\frac{1}{\sqrt{2}}$ A (D) $+j2$A

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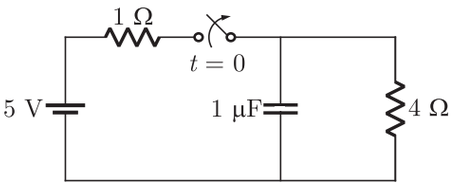
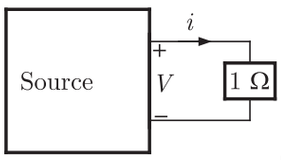
MCQ 1.2.29 The switch in the circuit has been closed for a long time. It is opened at $t = 0$. At $t = 0^+$, the current through the $1\,\mu$F capacitor is



(A) 0 A (B) 1 A
(C) 1.25 A (D) 5 A

MCQ 1.2.30 As shown in the figure, a $1\,\Omega$ resistance is connected across a source that has a load line $v + i = 100$. The current through the resistance is



(A) 25 A (B) 50 A
(C) 100 A (C) 200 A

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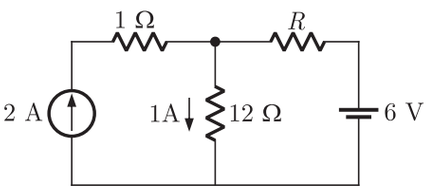
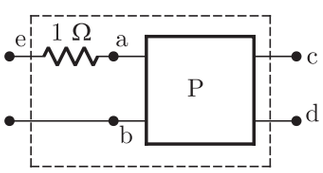
MCQ 1.2.31 If the $12\,\Omega$ resistor draws a current of 1 A as shown in the figure, the value of resistance R is



(A) $4\,\Omega$ (B) $6\,\Omega$
(C) $8\,\Omega$ (D) $18\,\Omega$

MCQ 1.2.32 The two-port network P shown in the figure has ports 1 and 2, denoted by terminals (a,b) and (c,d) respectively. It has an impedance matrix Z with parameters denoted by Z_{ij}. A $1\,\Omega$ resistor is connected in series with the network at port 1 as shown in the figure. The impedance matrix of the modified two-port network (shown as a dashed box) is



(A) $\begin{pmatrix} Z_{11}+1 & Z_{12}+1 \\ Z_{21} & Z_{22}+1 \end{pmatrix}$ (B) $\begin{pmatrix} Z_{11}+1 & Z_{12} \\ Z_{21} & Z_{22}+1 \end{pmatrix}$

(C) $\begin{pmatrix} Z_{11}+1 & Z_{12} \\ Z_{21} & Z_{22} \end{pmatrix}$ (D) $\begin{pmatrix} Z_{11}+1 & Z_{12} \\ Z_{21}+1 & Z_{22} \end{pmatrix}$

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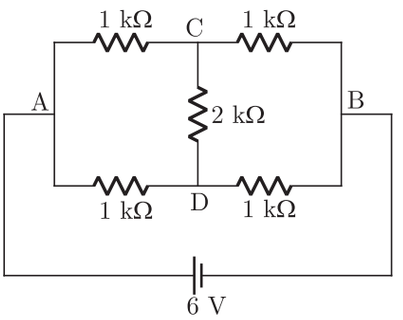
MCQ 1.2.33 The current through the 2 kΩ resistance in the circuit shown is



(A) 0 mA (B) 1 mA
(C) 2 mA (D) 6 mA

MCQ 1.2.34 How many 200 W/220 V incandescent lamps connected in series would consume the same total power as a single 100 W/220 V incandescent lamp ?
(A) not possible (B) 4
(C) 3 (D) 2

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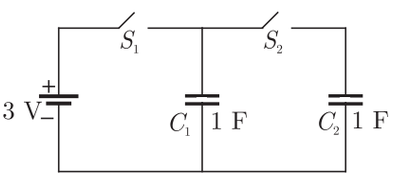
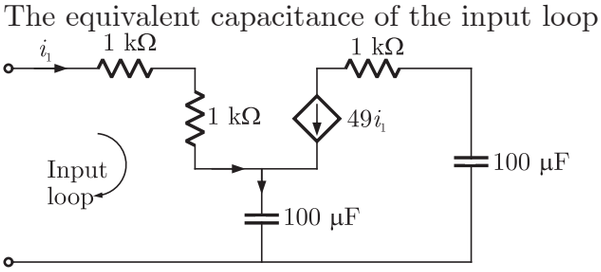
MCQ 1.2.35 In the figure shown, all elements used are ideal. For time $t < 0, S_1$ remained closed and S_2 open. At $t = 0, S_1$ is opened and S_2 is closed. If the voltage V_{c2} across the capacitor C_2 at $t = 0$ is zero, the voltage across the capacitor combination at $t = 0^+$ will be



(A) 1 V (B) 2 V
(C) 1.5 V (D) 3 V

MCQ 1.2.36 The equivalent capacitance of the input loop of the circuit shown is



(A) 2 μF (B) 100 μF
(C) 200 μF (D) 4 μF

MCQ 1.2.37 For the circuit shown, find out the current flowing through the 2 Ω resistance. Also identify the changes to be made to double the current through the 2 Ω resistance.

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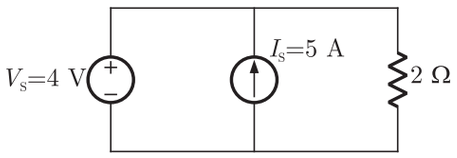
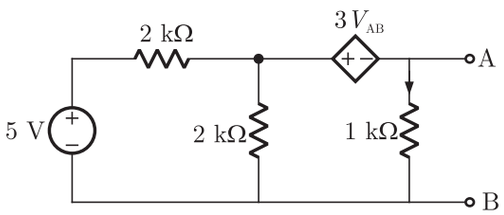


(A) (5 A; Put $V_S = 30$ V)
(B) (2 A; Put $V_S = 8$ V)
(C) (5 A; Put $I_S = 10$ A)
(D) (7 A; Put $I_S = 12$ A)

Statement for Linked Answer Question 38 and 39 :



MCQ 1.2.38 For the circuit given above, the Thevenin's resistance across the terminals A and B is

(A) 0.5 kΩ
(B) 0.2 kΩ
(C) 1 kΩ
(D) 0.11 kΩ

MCQ 1.2.39 For the circuit given above, the Thevenin's voltage across the terminals A and B is

(A) 1.25 V
(B) 0.25 V
(C) 1 V
(D) 0.5 V

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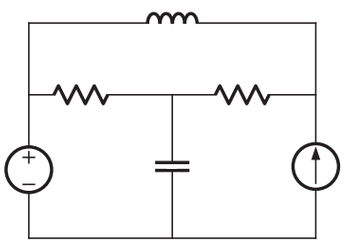
MCQ 1.2.40 The number of chords in the graph of the given circuit will be



(A) 3
(B) 4
(C) 5
(D) 6

MCQ 1.2.41 The Thevenin's equivalent of a circuit operation at $\omega = 5$ rads/s, has $V_{oc} = 3.71 + -15.9^{\circ}$ V and $Z_0 = 2.38 - j0.667\,\Omega$. At this frequency, the minimal realization of the Thevenin's impedance will have a

(A) resistor and a capacitor and an inductor
(B) resistor and a capacitor
(C) resistor and an inductor
(D) capacitor and an inductor

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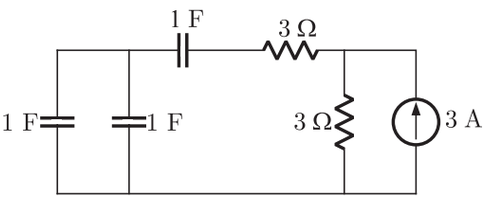
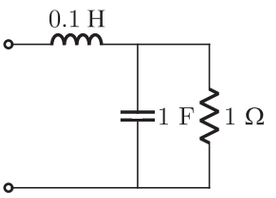
MCQ 1.2.42 The time constant for the given circuit will be



(A) 1/9 s (B) 1/4 s
(C) 4 s (D) 9 s

MCQ 1.2.43 The resonant frequency for the given circuit will be



(A) 1 rad/s (B) 2 rad/s
(C) 3 rad/s (D) 4 rad/s

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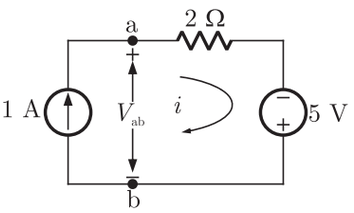
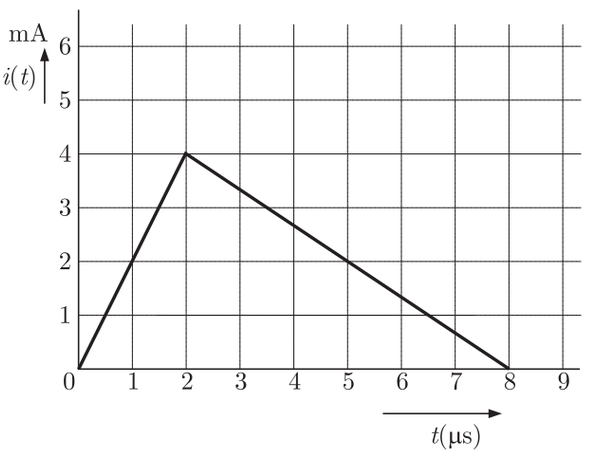
MCQ 1.2.44 Assuming ideal elements in the circuit shown below, the voltage V_{ab} will be



(A) −3 V (B) 0 V
(C) 3 V (D) 5 V

Statement for Linked Answer Question 38 and 39.

The current $i(t)$ sketched in the figure flows through a initially uncharged 0.3 nF capacitor.



MCQ 1.2.45 The charge stored in the capacitor at $t = 5\ \mu s$, will be

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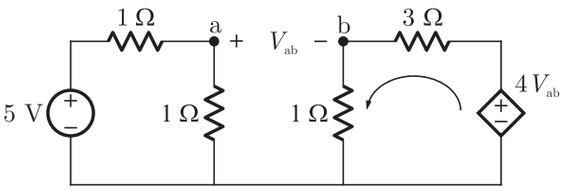
(A) 8 nC (B) 10 nC
(C) 13 nC (D) 16 nC

MCQ 1.2.46 The capacitor charged upto 5 ms, as per the current profile given in the figure, is connected across an inductor of 0.6 mH. Then the value of voltage across the capacitor after 1 μs will approximately be
(A) 18.8 V (B) 23.5 V
(C) -23.5 V (D) -30.6 V

MCQ 1.2.47 In the circuit shown in the figure, the value of the current i will be given by



(A) 0.31 A (B) 1.25 A
(C) 1.75 A (D) 2.5 A

MCQ 1.2.48 Two point charges $Q_1 = 10\,\mu$C and $Q_2 = 20$ mC are placed at coordinates (1,1,0) and $(-1,-1,0)$ respectively. The total electric flux passing through a plane $z = 20$ will be
(A) 7.5 μC (B) 13.5 μC
(C) 15.0 μC (D) 22.5 μC

MCQ 1.2.49 A capacitor consists of two metal plates each $500 \# 500$ mm^2 and spaced 6 mm apart. The space between the metal plates is filled with a glass plate of 4 mm thickness and a layer of paper of 2 mm thickness. The relative primitivities of the glass and paper are 8 and 2 respectively. Neglecting the fringing effect, the capacitance will be (Given that $\varepsilon_0 = 8.85 \# 10^{-12}$ F/m)
(A) 983.3 pF (B) 1475 pF
(C) 637.7 pF (D) 9956.25 pF

MCQ 1.2.50 A coil of 300 turns is wound on a non-magnetic core having a mean circumference of 300 mm and a cross-sectional area of 300 mm^2. The inductance of the coil corresponding to a magnetizing current of 3 A will be
(Given that $\mu_0 = 4\pi \# 10^{-7}$ H/m)
(A) 37.68 μH (B) 113.04 μH
(C) 3.768 μH (D) 1.1304 μH

YEAR 2007 ONE MARK

MCQ 1.2.51 Divergence of the vector field
$V(x,y,z) = -(x\cos xy + y)\hat{i} + (y\cos xy)\hat{j} + (\sin z^2 + x^2 + y^2)\hat{k}$ is
(A) $2z\cos z^2$ (B) $\sin xy + 2z\cos z^2$
(C) $x\sin xy - \cos z$ (D) None of these

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MCQ 1.2.52 The state equation for the current I_1 in the network shown below in terms of the

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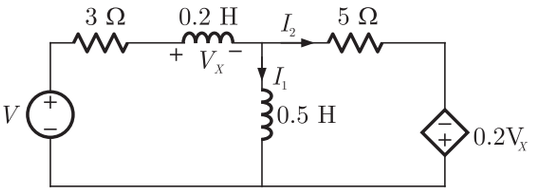
voltage V_X and the independent source V, is given by



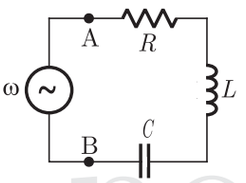
(A) $\frac{dI_1}{dt} = -1.4V_X - 3.75I_1 + \frac{5}{4}V$

(B) $\frac{dI_1}{dt} = 1.4V_X - 3.75I_1 - \frac{5}{4}V$

(C) $\frac{dI_1}{dt} = -1.4V_X + 3.75I_1 + \frac{5}{4}V$

(D) $\frac{dI_1}{dt} = -1.4V_X + 3.75I_1 - \frac{5}{4}V$

MCQ 1.2.53 The R-L-C series circuit shown in figure is supplied from a variable frequency voltage source. The admittance - locus of the R-L-C network at terminals AB for increasing frequency ω is



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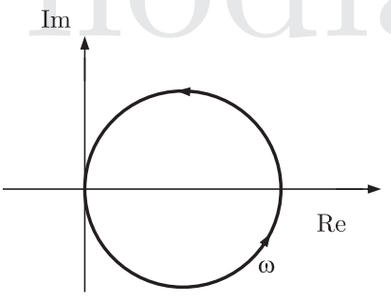
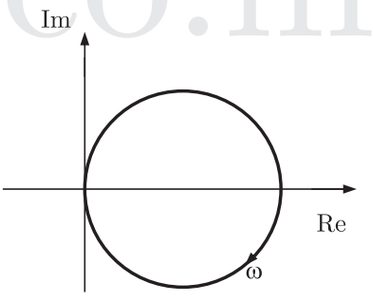
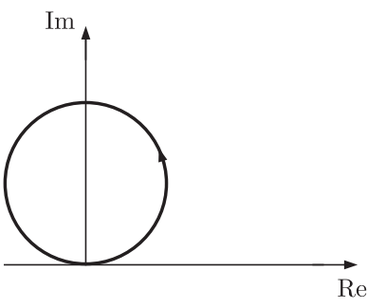
(A)



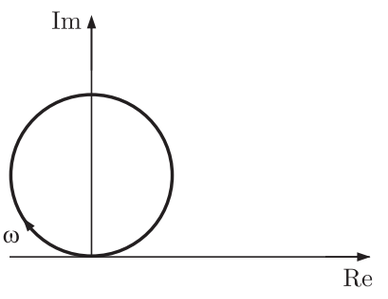
(B)



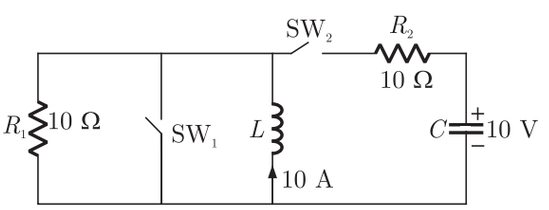
(C)



(D)



MCQ 1.2.54 In the circuit shown in figure. Switch SW_1 is initially closed and SW_2 is open. The inductor L carries a current of 10 A and the capacitor charged to 10 V with polarities as indicated. SW_2 is closed at $t = 0$ and SW_1 is opened at $t = 0$. The current through C and the voltage across L at $(t = 0^+)$ is



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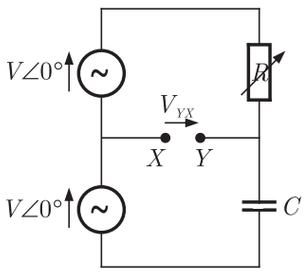
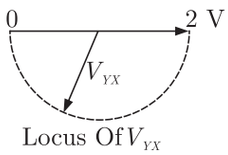
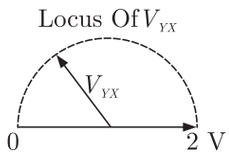
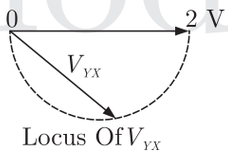
(A) 55 A, 4.5 V (B) 5.5 A, 45 V
(C) 45 A, 5.5 A (D) 4.5 A, 55 V

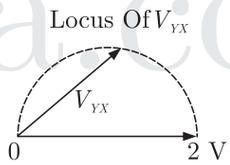
MCQ 1.2.55 In the figure given below all phasors are with reference to the potential at point "O". The locus of voltage phasor V_{YX} as R is varied from zero to infinity is shown by



(A)


(B)


(C)


(D)


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MCQ 1.2.56 A 3 V DC supply with an internal resistance of 2 Ω supplies a passive non-linear resistance characterized by the relation $V_{NL} = I_{NL}^2$. The power dissipated in the non linear resistance is

(A) 1.0 W (B) 1.5 W
(C) 2.5 W (D) 3.0 W

MCQ 1.2.57 The matrix A given below in the node incidence matrix of a network. The columns correspond to branches of the network while the rows correspond to nodes. Let $V = [V_1 V_2 ..... V_6]^T$ denote the vector of branch voltages while $I = [i_1 i_2 .....i_6]^T$ that of branch currents. The vector $E = [e_1 e_2 e_3 e_4]^T$ denotes the vector of node voltages relative to a common ground.

$$\begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & 1 & 0 \\ -1 & 0 & 0 & 0 & -1 & -1 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{bmatrix}$$

Which of the following statement is true ?

(A) The equations $V_1 - V_2 + V_3 = 0, V_3 + V_4 - V_5 = 0$ are KVL equations for the network for some loops

(B) The equations $V_1 - V_3 - V_6 = 0, V_4 + V_5 - V_6 = 0$ are KVL equations for the network for some loops

(C) $E = AV$

(D) $AV = 0$ are KVI equations for the network

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MCQ 1.2.58 A solid sphere made of insulating material has a radius R and has a total charge Q distributed uniformly in its volume. What is the magnitude of the electric field intensity, E, at a distance $r\,(0 < r < R)$ inside the sphere ?

(A) $\frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3}$ (B) $\frac{3}{4\pi\varepsilon_0}\frac{Qr}{R^3}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{QR}{r^3}$

Statement for Linked Answer Question 59 and 60.

An inductor designed with 400 turns coil wound on an iron core of 16 cm^2 cross sectional area and with a cut of an air gap length of 1 mm. The coil is connected to a 230 V, 50 Hz ac supply. Neglect coil resistance, core loss, iron reluctance and leakage inductance, $(\mu_0 = 4\pi \# 10^{-7}\ H/M)$

MCQ 1.2.59 The current in the inductor is

(A) 18.08 A (B) 9.04 A

(C) 4.56 A (D) 2.28 A

MCQ 1.2.60 The average force on the core to reduce the air gap will be

(A) 832.29 N (B) 1666.22 N

(C) 3332.47 N (D) 6664.84 N

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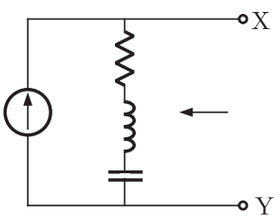
MCQ 1.2.61 In the figure the current source is $1+0$ A, $R = 1\,\Omega$, the impedances are $Z_C = -j\,\Omega$ and $Z_L = 2j\,\Omega$. The Thevenin equivalent looking into the circuit across X-Y is



(A) $\sqrt{2}+0$ V, $(1+2j)\,\Omega$ (B) $2+45°$ V, $(1-2j)\,\Omega$

(C) $2+45°$ V, $(1+j)\,\Omega$ (D) $\sqrt{2}+45°$ V, $(1+j)\,\Omega$

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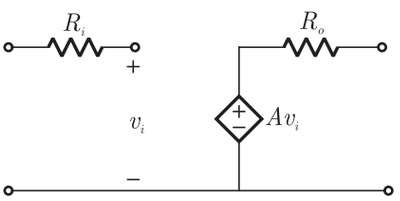
MCQ 1.2.62 The parameters of the circuit shown in the figure are $R_i = 1\,M\Omega$ $R_0 = 10\ \Omega$, $A = 10^6$ V/V If $v_i = 1\ \mu$V, the output voltage, input impedance and output impedance respectively are



(A) 1 V, 3, 10 Ω (B) 1 V, 0, 10 Ω

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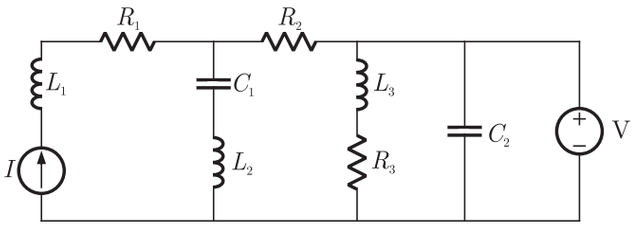
(C) 1 V, 0, 3 (D) 10 V, 3, 10 Ω

MCQ 1.2.63 In the circuit shown in the figure, the current source $I = 1\,\text{A}$, the voltage source $V = 5\,\text{V}, R_1 = R_2 = R_3 = 1\,\Omega, L_1 = L_2 = L_3 = 1\,\text{H}, C_1 = C_2 = 1\,\text{F}$

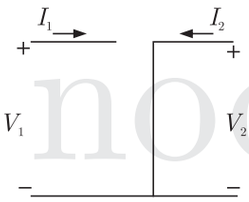


The currents (in A) through R_3 and through the voltage source V respectively will be

(A) 1, 4 (B) 5, 1

(C) 5, 2 (D) 5, 4

MCQ 1.2.64 The parameter type and the matrix representation of the relevant two port parameters that describe the circuit shown are



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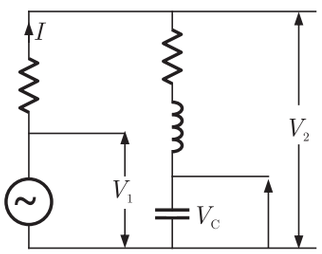
(A) z parameters, $\begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$ (B) h parameters, $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

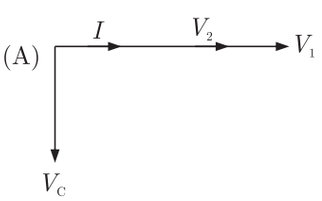
(C) h parameters, $\begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$ (D) z parameters, $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

MCQ 1.2.65 The circuit shown in the figure is energized by a sinusoidal voltage source V_1 at a frequency which causes resonance with a current of I.

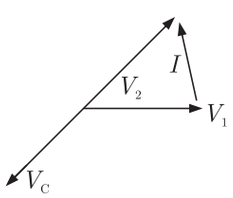


The phasor diagram which is applicable to this circuit is

(A)



(B)



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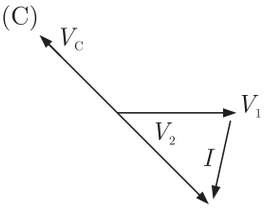
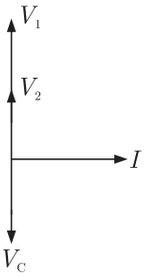
(C)



(D)



MCQ 1.2.66 An ideal capacitor is charged to a voltage V_0 and connected at $t = 0$ across an ideal inductor L. (The circuit now consists of a capacitor and inductor alone). If we let $\omega_0 = \frac{1}{\sqrt{LC}}$, the voltage across the capacitor at time $t > 0$ is given by

(A) V_0 (B) $V_0 \cos(\omega_0 t)$

(C) $V_0 \sin(\omega_0 t)$ (D) $V_0 e^{-\omega_0 t} \cos(\omega_0 t)$

MCQ 1.2.67 An energy meter connected to an immersion heater (resistive) operating on an AC 230 V, 50 Hz, AC single phase source reads 2.3 units (kWh) in 1 hour. The heater is removed from the supply and now connected to a 400 V peak square wave source of 150 Hz. The power in kW dissipated by the heater will be

(A) 3.478 (B) 1.739

(C) 1.540 (D) 0.870

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MCQ 1.2.68 Which of the following statement holds for the divergence of electric and magnetic flux densities ?

(A) Both are zero

(B) These are zero for static densities but non zero for time varying densities.

(C) It is zero for the electric flux density

(D) It is zero for the magnetic flux density

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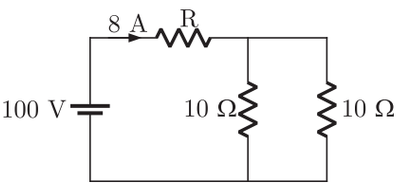
MCQ 1.2.69 In the figure given below the value of R is



(A) 2.5 Ω (B) 5.0 Ω

(C) 7.5 Ω (D) 10.0 Ω

MCQ 1.2.70 The RMS value of the voltage $u(t) = 3 + 4\cos(3t)$ is

(A) $\sqrt{17}$ V (B) 5 V

(C) 7 V (D) $(3 + 2\sqrt{2})$ V

MCQ 1.2.71 For the two port network shown in the figure the Z-matrix is given by

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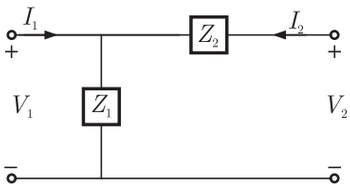
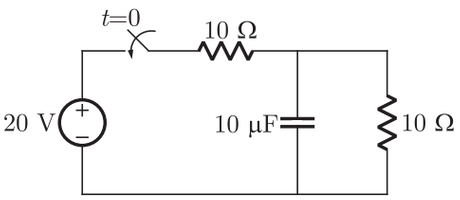


(A) $\begin{bmatrix} Z_1 & Z_1+Z_2 \\ Z_1+Z_2 & Z_2 \end{bmatrix}$ (B) $\begin{bmatrix} Z_1 & Z_1 \\ Z_1+Z_2 & Z_2 \end{bmatrix}$

(C) $\begin{bmatrix} Z_1 & Z_2 \\ Z_2 & Z_1+Z_2 \end{bmatrix}$ (D) $\begin{bmatrix} Z_1 & Z_1 \\ Z_1 & Z_1+Z_2 \end{bmatrix}$

MCQ 1.2.72 In the figure given, for the initial capacitor voltage is zero. The switch is closed at $t = 0$. The final steady-state voltage across the capacitor is



(A) 20 V (B) 10 V

(C) 5 V (D) 0 V

MCQ 1.2.73 If $\vec{E}$ is the electric intensity, $\nabla \cdot (\nabla \times \vec{E})$ is equal to

(A) $\vec{E}$ (B) $|\vec{E}|$

(C) null vector (D) Zero

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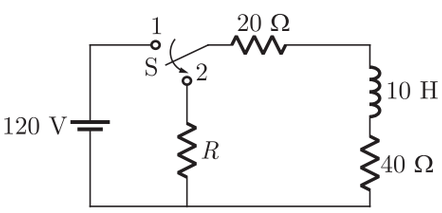
Statement for Linked Answer Question 74 and 75.

A coil of inductance 10 H and resistance 40 Ω is connected as shown in the figure. After the switch S has been in contact with point 1 for a very long time, it is moved to point 2 at, $t = 0$.

MCQ 1.2.74 If, at t = 0^+, the voltage across the coil is 120 V, the value of resistance R is



(A) 0 Ω (B) 20 Ω

(C) 40 Ω (D) 60 Ω

MCQ 1.2.75 For the value as obtained in (a), the time taken for 95% of the stored energy to be dissipated is close to

(A) 0.10 sec (B) 0.15 sec

(C) 0.50 sec (D) 1.0 sec

MCQ 1.2.76 The RL circuit of the figure is fed from a constant magnitude, variable frequency

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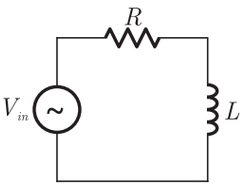
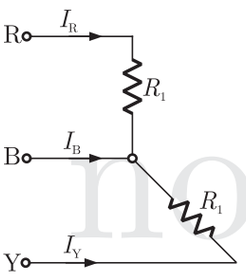
sinusoidal voltage source V_{in}. At 100 Hz, the R and L elements each have a voltage drop μ_{RMS}.If the frequency of the source is changed to 50 Hz, then new voltage drop across R is



(A) $\sqrt{\frac{5}{8}}\,u_{RMS}$ (B) $\sqrt{\frac{2}{3}}\,u_{RMS}$

(C) $\sqrt{\frac{8}{5}}\,u_{RMS}$ (D) $\sqrt{\frac{3}{2}}\,u_{RMS}$

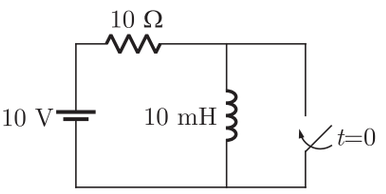
MCQ 1.2.77 For the three-phase circuit shown in the figure the ratio of the currents $I_R : I_Y : I_B$ is given by



(A) $1:1:\sqrt{3}$ (B) $1:1:2$

(C) $1:1:0$ (D) $1:1:\sqrt{3/2}$

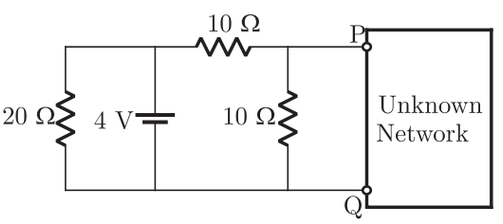
MCQ 1.2.78 The circuit shown in the figure is in steady state, when the switch is closed at $t = 0$.Assuming that the inductance is ideal, the current through the inductor at $t = 0^+$ equals



(A) 0 A (B) 0.5 A

(C) 1 A (D) 2 A

MCQ 1.2.79 In the given figure, the Thevenin's equivalent pair (voltage, impedance), as seen at the terminals P-Q, is given by



(A) $(2\,V, 5\,\Omega)$ (B) $(2\,V, 7.5\,\Omega)$

(C) $(4\,V, 5\,\Omega)$ (D) $(4\,V, 7.5\,\Omega)$

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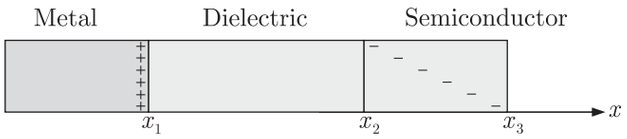
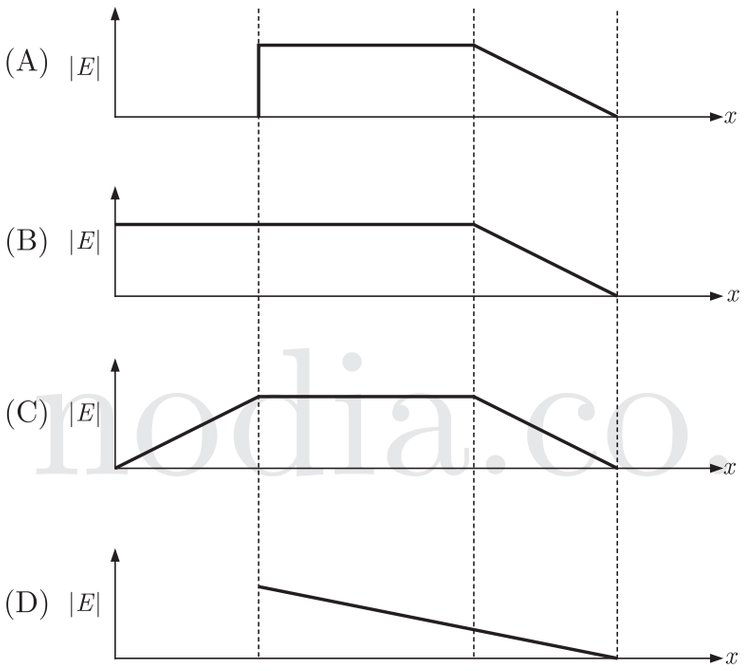
MCQ 1.2.80 The charge distribution in a metal-dielectric-semiconductor specimen is shown in the figure. The negative charge density decreases linearly in the semiconductor as shown. The electric field distribution is as shown in





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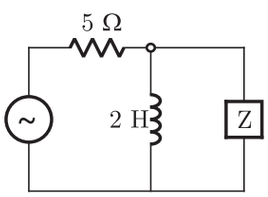
MCQ 1.2.81 The value of Z in figure which is most appropriate to cause parallel resonance at 500 Hz is



(A) 125.00 mH
(B) 304.20 μF
(C) 2.0 μF
(D) 0.05 μF

MCQ 1.2.82 A parallel plate capacitor is shown in figure. It is made two square metal plates of 400 mm side. The 14 mm space between the plates is filled with two layers of dielectrics of $\varepsilon_r = 4$, 6 mm thick and $\varepsilon_r = 2$, 8 mm thick. Neglecting fringing of fields at the edge the capacitance is

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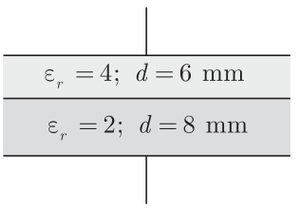

(A) 1298 pF (B) 944 pF
(C) 354 pF (D) 257 pF

MCQ 1.2.83 The inductance of a long solenoid of length 1000 mm wound uniformly with 3000 turns on a cylindrical paper tube of 60 mm diameter is
(A) 3.2 μH (B) 3.2 mH
(C) 32.0 mH (D) 3.2 H

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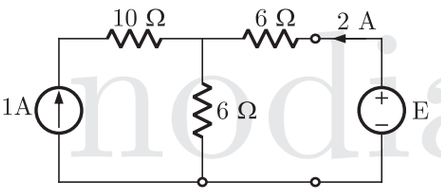
MCQ 1.2.84 In figure, the value of the source voltage is



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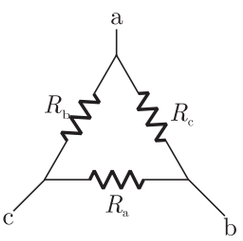
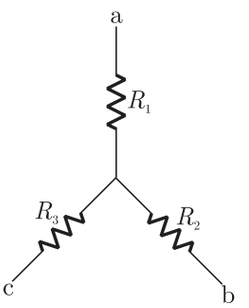
(A) 12 V (B) 24 V
(C) 30 V (D) 44 V

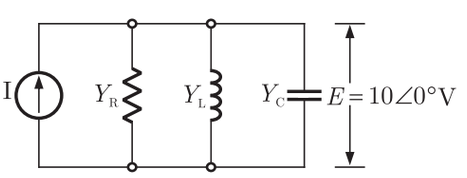
MCQ 1.2.85 In figure, R_a, R_b and R_c are 20 Ω, 20 Ω and 10 Ω respectively. The resistances R_1, R_2 and R_3 in Ω of an equivalent star-connection are





(A) 2.5, 5, 5 (B) 5, 2.5, 5
(C) 5, 5, 2.5 (D) 2.5, 5, 2.5

MCQ 1.2.86 In figure, the admittance values of the elements in Siemens are $Y_R = 0.5 + j0, Y_L = 0 - j1.5, Y_C = 0 + j0.3$ respectively. The value of I as a phasor when the voltage E across the elements is $10 + 0^\circ$ V



(A) $1.5 + j0.5$ (B) $5 - j18$

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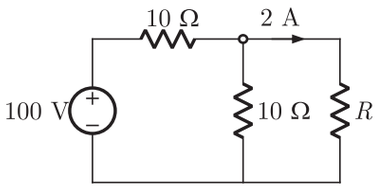
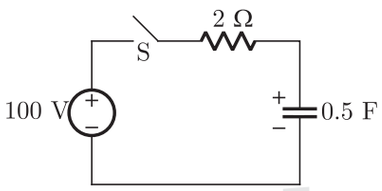
(C) $0.5 + j1.8$ (D) $5 - j12$

MCQ 1.2.87 In figure, the value of resistance R in Ω is



(A) 10 (B) 20
(C) 30 (D) 40

MCQ 1.2.88 In figure, the capacitor initially has a charge of 10 Coulomb. The current in the circuit one second after the switch S is closed will be



(A) 14.7 A (B) 18.5 A
(C) 40.0 A (D) 50.0 A

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MCQ 1.2.89 The rms value of the current in a wire which carries a d.c. current of 10 A and a sinusoidal alternating current of peak value 20 A is
(A) 10 A (B) 14.14 A
(C) 15 A (D) 17.32 A

MCQ 1.2.90 The Z-matrix of a 2-port network as given by $\begin{bmatrix} 0.9 & 0.2 \\ 0.2 & 0.6 \end{bmatrix}$
The element Y_{22} of the corresponding Y-matrix of the same network is given by
(A) 1.2 (B) 0.4
(C) -0.4 (D) 1.8

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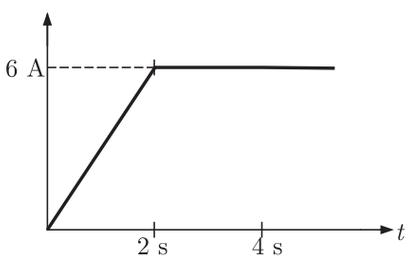
MCQ 1.2.91 Figure Shows the waveform of the current passing through an inductor of resistance $1\,\Omega$ and inductance 2 H. The energy absorbed by the inductor in the first four seconds is



(A) 144 J (B) 98 J
(C) 132 J (D) 168 J

MCQ 1.2.92 A segment of a circuit is shown in figure $v_R = 5V$, $v_c = 4\sin 2t$. The voltage v_L is

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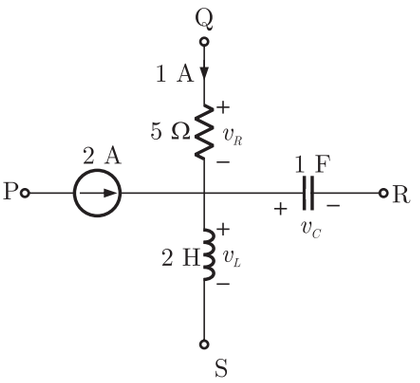
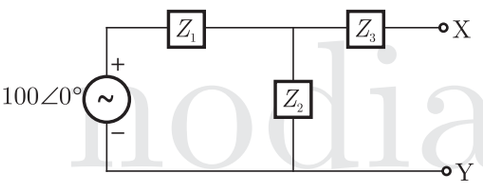
given by



(A) $3 - 8\cos 2t$ (B) $32\sin 2t$

(C) $16\sin 2t$ (D) $16\cos 2t$

MCQ 1.2.93 In the figure, $Z_1 = 10 + -60^\circ, Z_2 = 10 + 60^\circ, Z_3 = 50 + 53.13^\circ$. Thevenin impedance seen form X-Y is



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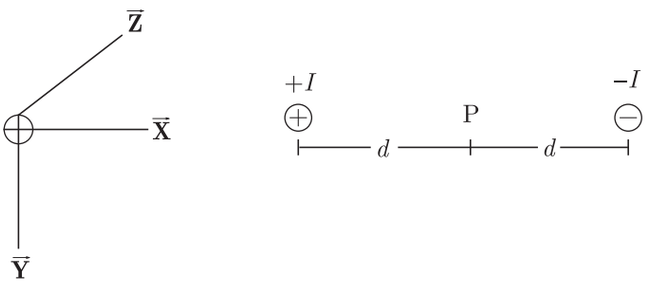
(A) $56.66 + 45^\circ$ (B) $60 + 30^\circ$

(C) $70 + 30^\circ$ (D) $34.4 + 65^\circ$

MCQ 1.2.94 Two conductors are carrying forward and return current of +I and $-I$ as shown in figure. The magnetic field intensity $\vec{\mathrm{H}}$ at point P is



(A) $\frac{I}{\pi d}\vec{\mathrm{Y}}$ (B) $\frac{I}{\pi d}\vec{\mathrm{X}}$

(C) $\frac{I}{2\pi d}\vec{\mathrm{Y}}$ (D) $\frac{I}{2\pi d}\vec{\mathrm{X}}$

MCQ 1.2.95 Two infinite strips of width w m in x-direction as shown in figure, are carrying forward and return currents of +I and $-I$ in the z- direction. The strips are separated by distance of x m. The inductance per unit length of the configuration is measured to be L H/m. If the distance of separation between the strips in snow reduced to x/2 m, the inductance per unit length of the configuration is

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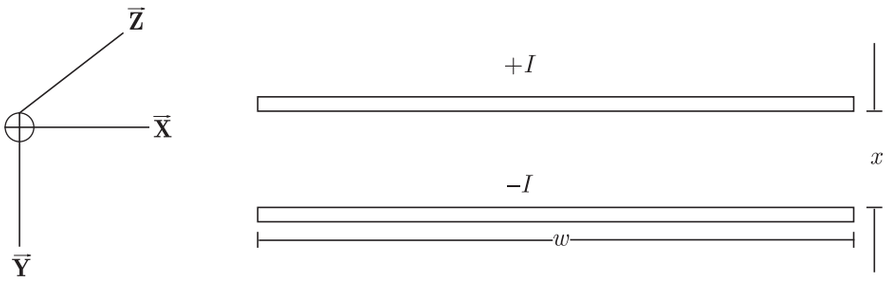

(A) $2L$ H/m
(B) $L/4$ H/m
(C) $L/2$ H/m
(D) $4L$ H/m

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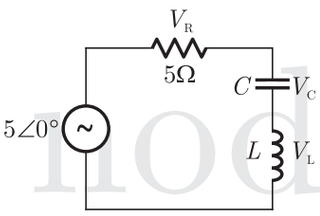
MCQ 1.2.96 In the circuit of figure, the magnitudes of V_L and V_C are twice that of V_R. Given that $f = 50$ Hz, the inductance of the coil is



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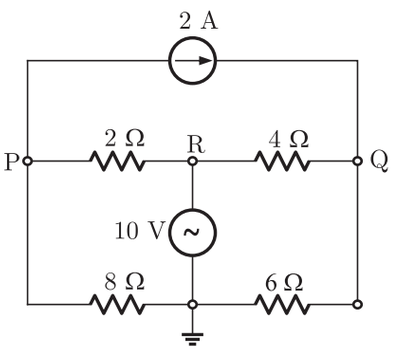
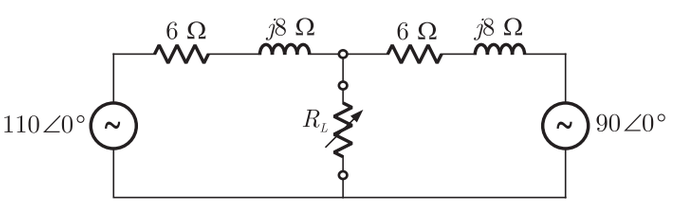
(A) 2.14 mH
(B) 5.30 H
(C) 31.8 mH
(D) 1.32 H

MCQ 1.2.97 In figure, the potential difference between points P and Q is



(A) 12 V
(B) 10 V
(C) -6 V
(D) 8 V

MCQ 1.2.98 Two ac sources feed a common variable resistive load as shown in figure. Under the maximum power transfer condition, the power absorbed by the load resistance R_L is



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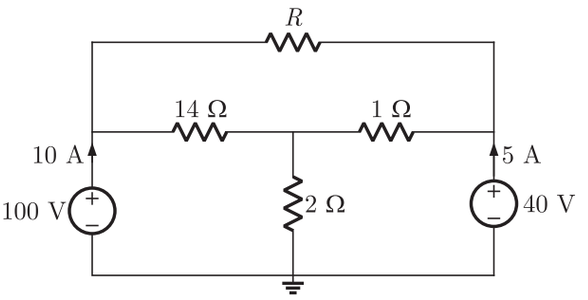
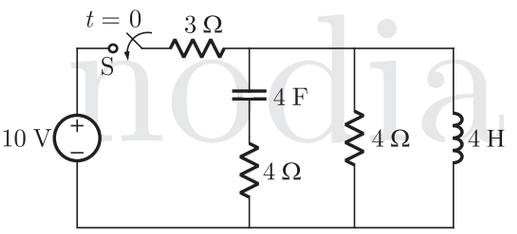
(A) 2200 W (B) 1250 W
(C) 1000 W (D) 625 W

MCQ 1.2.99 In figure, the value of R is



(A) 10 Ω (B) 18 Ω
(C) 24 Ω (D) 12 Ω

MCQ 1.2.100 In the circuit shown in figure, the switch S is closed at time (t = 0). The voltage across the inductance at $t = 0^+$, is



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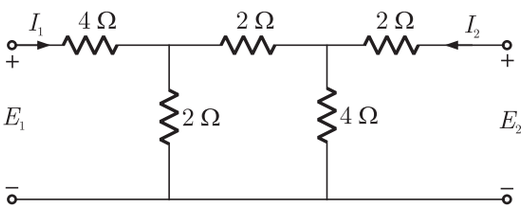
(A) 2 V (B) 4 V
(C) −6 V (D) 8 V

MCQ 1.2.101 The h-parameters for a two-port network are defined by

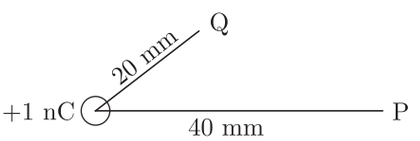
$$\begin{bmatrix} E_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ E_2 \end{bmatrix}$$

For the two-port network shown in figure, the value of h_{12} is given by



(A) 0.125 (B) 0.167
(C) 0.625 (D) 0.25

MCQ 1.2.102 A point charge of +I nC is placed in a space with permittivity of $8.85 \# 10^{-12}$ F/m as shown in figure. The potential difference V_{PQ} between two points P and Q at distance of 40 mm and 20 mm respectively fr0m the point charge is



(A) 0.22 kV (B) −225 V

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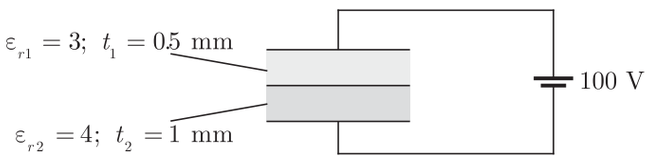
(C) -2.24 kV (D) 15 V

MCQ 1.2.103 A parallel plate capacitor has an electrode area of 100 mm^2, with spacing of 0.1 mm between the electrodes. The dielectric between the plates is air with a permittivity of $8.85 \# 10^{-12}$ F/m. The charge on the capacitor is 100 V. The stored energy in the capacitor is

(A) 8.85 pJ (B) 440 pJ

(C) 22.1 nJ (D) 44.3 nJ

MCQ 1.2.104 A composite parallel plate capacitor is made up of two different dielectric material with different thickness (t_1 and t_2) as shown in figure. The two different dielectric materials are separated by a conducting foil F. The voltage of the conducting foil is



(A) 52 V (B) 60 V

(C) 67 V (D) 33 V

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MCQ 1.2.105 A current impulse, $5\delta(t)$, is forced through a capacitor C. The voltage , $v_c(t)$, across the capacitor is given by

(A) $5t$ (B) $5u(t) - C$

(C) $\frac{5}{C}t$ (D) $\frac{5u(t)}{C}$

MCQ 1.2.106 The graph of an electrical network has N nodes and B branches. The number of links L, with respect to the choice of a tree, is given by

(A) $B - N + 1$ (B) $B + N$

(C) $N - B + 1$ (D) $N - 2B - 1$

MCQ 1.2.107 Given a vector field $\vec{F}$, the divergence theorem states that

(A) $\int_S \vec{F} \cdot d\vec{S} = \int_V \vec{\nabla} \cdot \vec{F} dV$ (B) $\int_S \vec{F} \cdot d\vec{S} = \int_V \vec{\nabla} \times \vec{F} dV$

(C) $\int_S \vec{F} \times d\vec{S} = \int_V \vec{\nabla} \cdot \vec{F} dV$ (D) $\int_S \vec{F} \times d\vec{S} = \int_V \vec{\nabla} \cdot \vec{F} dV$

MCQ 1.2.108 Consider a long, two-wire line composed of solid round conductors. The radius of both conductors. The radius of both conductors is 0.25 cm and the distance between their centres is 1 m. If this distance is doubled, then the inductance per unit length

(A) doubles

(B) halves

(C) increases but does not double

(D) decreases but does not halve

MCQ 1.2.109 A long wire composed of a smooth round conductor runs above and parallel to the ground (assumed to be a large conducting plane). A high voltage exists

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between the conductor and the ground. The maximum electric stress occurs at
(A) The upper surface of the conductor
(B) The lower surface of the conductor.
(C) The ground surface.
(D) midway between the conductor and ground.

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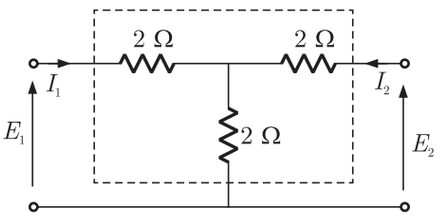
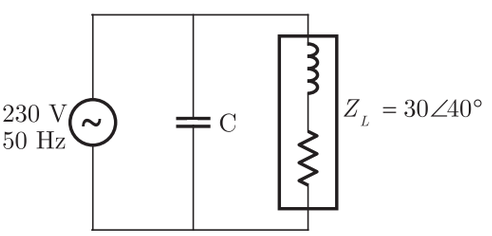
MCQ 1.2.110 A two port network shown in Figure, is described by the following equations

$$I_1 = Y_{11}E_1 + Y_{12}E_2$$
$$I_1 = Y_{21}E_1 + Y_{22}E_2$$



The admittance parameters, Y_{11}, Y_{12}, Y_{21} and Y_{22} for the network shown are
(A) 0.5 mho, 1 mho, 2 mho and 1 mho respectively
(B) $\frac{1}{3}$ mho, $-\frac{1}{6}$ mho, $-\frac{1}{6}$ mho and $\frac{1}{3}$ mho respectively
(C) 0.5 mho, 0.5 mho, 1.5 mho and 2 mho respectively
(D) $-\frac{2}{5}$ mho, $-\frac{3}{7}$ mho, $\frac{3}{7}$ mho and $\frac{2}{5}$ mho respectively

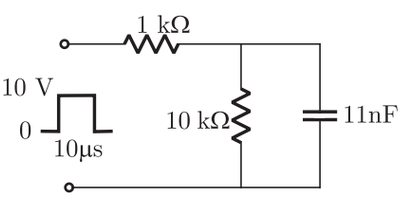
MCQ 1.2.111 In the circuit shown in Figure, what value of C will cause a unity power factor at the ac source ?



(A) 68.1 μF
(B) 165 μF
(C) 0.681 μF
(D) 6.81 μF

MCQ 1.2.112 A series R-L-C circuit has $R = 50\,\Omega$; $L = 100$ μH and $C = 1$ μF. The lower half power frequency of the circuit is
(A) 30.55 kHz
(B) 3.055 kHz
(C) 51.92 kHz
(D) 1.92 kHz

MCQ 1.2.113 A 10 V pulse of 10 μs duration is applied to the circuit shown in Figure, assuming that the capacitor is completely discharged prior to applying the pulse, the peak value of the capacitor voltage is



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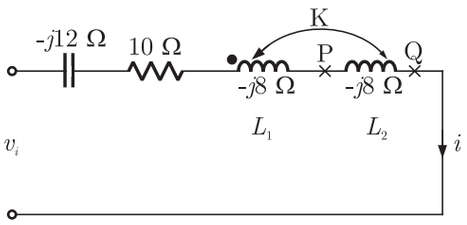
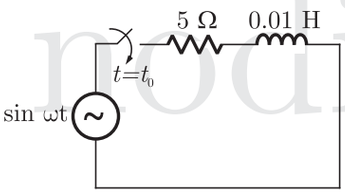
(A) 11 V (B) 5.5 V
(C) 6.32 V (D) 0.96 V

MCQ 1.2.114 In the circuit shown in Figure, it is found that the input voltage (v_i) and current i are in phase. The coupling coefficient is $K = \frac{M}{\sqrt{L_1 L_2}}$, where M is the mutual inductance between the two coils.
The value of K and the dot polarity of the coil P-Q are



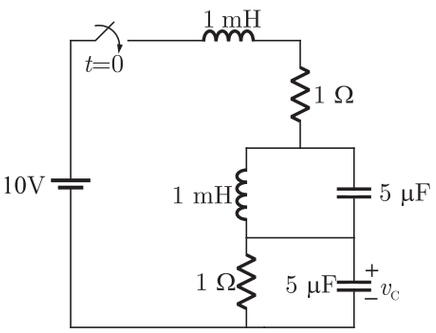
(A) $K = 0.25$ and dot at P (B) $K = 0.5$ and dot at P
(C) $K = 0.25$ and dot at Q (C) $K = 0.5$ and dot at Q

MCQ 1.2.115 Consider the circuit shown in Figure If the frequency of the source is 50 Hz, then a value of t_0 which results in a transient free response is



(A) 0 ms (B) 1.78 ms
(C) 2.71 ms (D) 2.91 ms

MCQ 1.2.116 In the circuit shown in figure, the switch is closed at time $t = 0$. The steady state value of the voltage v_c is



(A) 0 V (B) 10 V
(C) 5 V (D) 2.5 V

Common data Question for Q. 117-118* :

A constant current source is supplying 10 A current to a circuit shown in figure. The switch is initially closed for a sufficiently long time, is suddenly opened at $t = 0$

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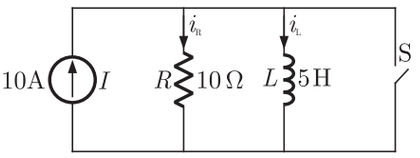


MCQ 1.2.117 The inductor current $i_L(t)$ will be

(A) 10 A (B) 0 A

(C) $10e^{-2t}$ A (D) $10(1-e^{-2t})$ A

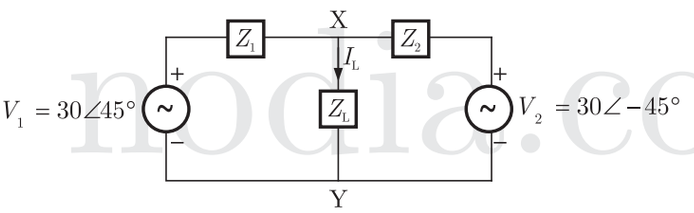
MCQ 1.2.118 What is the energy stored in L, a long time after the switch is opened

(A) Zero (B) 250 J

(C) 225 J (D) 2.5 J

Common Data Question for Q. 119-120* :

An electrical network is fed by two ac sources, as shown in figure, Given that $Z_1 = (1-j)\,\Omega$, $Z_2 = (1+j)\,\Omega$ and $Z_L = (1+j0)\,\Omega$.



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MCQ 1.2.119 *Thevenin voltage and impedance across terminals X and Y respectively are

(A) 0 V, $(2+2j)\,\Omega$ (B) 60 V, $1\,\Omega$

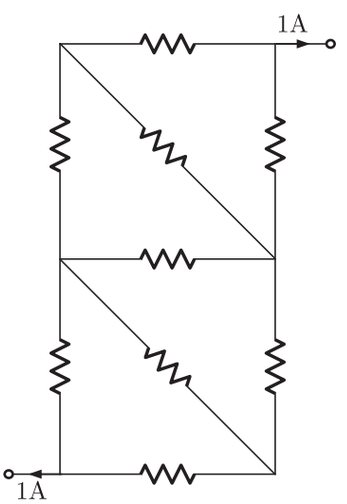
(C) 0 V, $1\,\Omega$ (D) 30 V, $(1+j)\,\Omega$

MCQ 1.2.120 *Current i_L through load is

(A) 0 A (B) 1 A

(C) 0.5 A (D) 2 A

MCQ 1.2.121 *In the resistor network shown in figure, all resistor values are $1\,\Omega$. A current of 1 A passes from terminal a to terminal b as shown in figure, Voltage between terminal a and b is



(A) 1.4 Volt (B) 1.5 Volt

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(C) 0 Volt (D) 3 Volt

YEAR 2001 ONE MARK

MCQ 1.2.122 In a series RLC circuit at resonance, the magnitude of the voltage developed across the capacitor

(A) is always zero

(B) can never be greater than the input voltage

(C) can be greater than the input voltage, however it is 90° out of phase with the input voltage

(D) can be greater than the input voltage, and is in phase with the input voltage.

MCQ 1.2.123 Two incandescent light bulbs of 40 W and 60 W rating are connected in series across the mains. Then

(A) the bulbs together consume 100 W

(B) the bulbs together consume 50 W

(C) the 60 W bulb glows brighter

(D) the 40 bulb glows brighter

MCQ 1.2.124 A unit step voltage is applied at $t = 0$ to a series RL circuit with zero initial conditions.

(A) It is possible for the current to be oscillatory.

(B) The voltage across the resistor at $t = 0^+$ is zero.

(C) The energy stored in the inductor in the steady state is zero.

(D) The resistor current eventually falls to zero.

MCQ 1.2.125 Given two coupled inductors L_1 and L_2, their mutual inductance M satisfies

(A) $M = \sqrt{L_1^2 + L_2^2}$ (B) $M > \dfrac{(L_1 + L_2)}{2}$

(C) $M > \sqrt{L_1 L_2}$ (D) $M \leq \sqrt{L_1 L_2}$

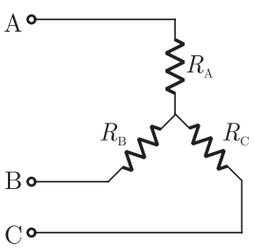
MCQ 1.2.126 A passive 2-port network is in a steady-state. Compared to its input, the steady state output can never offer

(A) higher voltage (B) lower impedance

(C) greater power (D) better regulation

YEAR 2001 TWO MARKS

MCQ 1.2.127 Consider the star network shown in Figure The resistance between terminals A and B with C open is 6 Ω, between terminals B and C with A open is 11 Ω, and between terminals C and A with B open is 9 Ω. Then



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(A) $R_A = 4\,\Omega, R_B = 2\,\Omega, R_C = 5\,\Omega$

(B) $R_A = 2\,\Omega, R_B = 4\,\Omega, R_C = 7\,\Omega$

(C) $R_A = 3\,\Omega, R_B = 3\,\Omega, R_C = 4\,\Omega$

(D) $R_A = 5\,\Omega, R_B = 1\,\Omega, R_C = 10\,\Omega$

MCQ 1.2.128 A connected network of $N > 2$ nodes has at most one branch directly connecting any pair of nodes. The graph of the network

(A) Must have at least N branches for one or more closed paths to exist

(B) Can have an unlimited number of branches

(C) can only have at most N branches

(D) Can have a minimum number of branches not decided by N

MCQ 1.2.129 A 240 V single-phase ac source is connected to a load with an impedance of $10\angle 60^\circ\,\Omega$. A capacitor is connected in parallel with the load. If the capacitor suplies 1250 VAR, the real power supplied by the source is

(A) 3600 W (B) 2880 W

(C) 240 W (D) 1200 W

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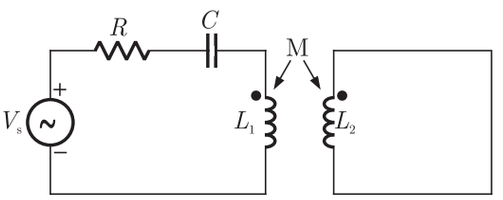
Common Data Questions Q.130-131*:

For the circuit shown in figure given values are
$R = 10\,\Omega$, $C = 3\,\mu$F, $L_1 = 40$ mH, $L_2 = 10$ mH and $M = 10$ mH



MCQ 1.2.130 The resonant frequency of the circuit is

A) $\frac{1}{3} \times 10^5$ rad/sec (B) $\frac{1}{2}$ # 10^5 rad/sec

(C) $\frac{1}{\sqrt{21}}$ # 10^5 rad/sec (D) $\frac{1}{9}$ # 10^5 rad/sec

MCQ 1.2.131 The Q-factor of the circuit in Q.82 is

(A) 10 (B) 350

(C) 101 (D) 15

MCQ 1.2.132 Given the potential function in free space to be $V(x) = (50x^2 + 50y^2 + 50z^2)$ volts, the magnitude (in volts/metre) and the direction of the electric field at a point (1,-1,1), where the dimensions are in metres, are

(A) $100; (\hat{i} + \hat{j} + \hat{k})$ (B) $100/\sqrt{3}; (\hat{i} - \hat{j} + \hat{k})$

(C) $100\sqrt{3}; [(-\hat{i} + \hat{j} - \hat{k})/\sqrt{3}]$ (D) $100\sqrt{3}; [(-\hat{i} - \hat{j} - \hat{k})/\sqrt{3}]$

MCQ 1.2.133 The hysteresis loop of a magnetic material has an area of 5 cm^2 with the scales given as 1 cm = 2 AT and 1 cm = 50 mWb. At 50 Hz, the total hysteresis loss is.

(A) 15 W (B) 20 W

(C) 25 W (D) 50 W

MCQ 1.2.134 The conductors of a 10 km long, single phase, two wire line are separated by a

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distance of 1.5 m. The diameter of each conductor is 1 cm. If the conductors are of copper, the inductance of the circuit is

(A) 50.0 mH (B) 45.3 mH

(C) 23.8 mH (D) 19.6 mH

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SOLUTION

SOL 1.2.1 Option (B) is correct.

In the equivalent star connection, the resistance can be given as

$$R_C = \frac{R_b R_a}{R_a + R_b + R_c}$$

$$R_B = \frac{R_a R_c}{R_a + R_b + R_c}$$

$$R_A = \frac{R_b R_c}{R_a + R_b + R_c}$$

So, if the delta connection components R_a, R_b and R_c are scaled by a factor k then

$$R_A' = \frac{(k\,R_b)(k\,R_c)}{kR_a + kR_b + kR_c}$$

$$= \frac{k^2}{k}\frac{R_b R_c}{R_a + R_b + R_c}$$

$$= k\,R_A$$

Hence, it is also scaled by a factor k

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SOL 1.2.2 Option (A) is correct.

Given, flux density

$$\vec{B} = 4x\,\vec{a}_x + 2ky\,\vec{a}_y + 8\,\vec{a}_z$$

Since, magnetic flux density is always divergence less.

i.e., $\nabla\cdot\vec{B} = 0$

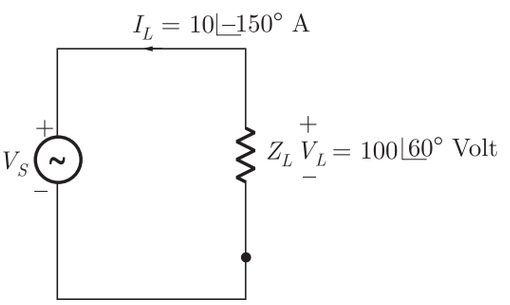
So, for given vector flux density, we have

$$\nabla\cdot\vec{B} = 4 + 2k + 0 = 0$$

or, $k = -2$

SOL 1.2.3 Option (B) is correct.

Consider the voltage source and load shown in figure



We obtain the power delivered by load as

$$P_{delivered} = I_L^* V_L$$

$$= (10\angle +150°)(10\angle 60°)$$

$$= 100\angle 210°$$

$$= 1000\cos 210° + j1000\sin 210°$$

$$= -866.025 - j500$$

As both the reactive and average power (real power) are negative so, power is

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absorbed by load. i.e., load absorbs real as well as reactive power.

SOL 1.2.4 Option (C) is correct.

For the purely resistive load, maximum average power is transferred when

$$R_L = \sqrt{R_{Th}^2 + X_{Th}^2}$$

where $R_{Th} + jX_{Th}$ is the equivalent thevinin (input) impedance of the circuit.

i.e., $$R_L = \sqrt{4^2 + 3^2}$$
$$= 5\,\Omega$$

SOL 1.2.5 Option (D) is correct.

For the given capacitance, $C = 100\mu F$ in the circuit, we have the reactance.

$$X_C = \frac{1}{sc}$$
$$= \frac{1}{s \times 100 \times 10^{-6}}$$
$$= \frac{10^4}{s}$$

So,

$$\frac{V_2(s)}{V_1(s)} = \frac{\frac{10^4}{s} + 10^4}{\frac{10^4}{s} + 10^4 + \frac{10^4}{s}}$$
$$= \frac{s+1}{s+2}$$

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SOL 1.2.6 Option (B) is correct.

Energy density stored in a dielectric medium is obtained as

$$w_E = \frac{1}{2}\varepsilon |E|^2 \text{ J/m}^2$$

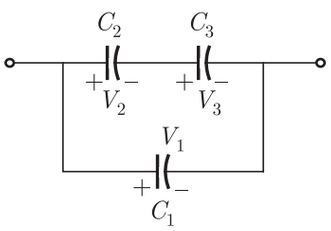
The electric field inside the dielectric will be same to given field in free space only if the field is tangential to the interface

So, $$w_E = \frac{1}{2} 2\varepsilon_0 \left(\sqrt{6^2 + 8^2}\right)^2 \times 10^6 \text{ /mm}^2$$

Therefore, the total stored energy is

$$W_E = \int_v W_E \, dv$$
$$= \varepsilon_0 100 \times 10^6/\text{mm}^2 \times (500 \times 500)\text{mm}^2 \times (0.4)$$
$$= \varepsilon_0 \times 100 \times 10^6 \times 0.4 \times 25 \times 10^4$$
$$= 8.85 \times 10^{-12} \times 10^{13}$$
$$= 88.5\,\text{J}$$

SOL 1.2.7 Option (C) is correct.



Consider that the voltage across the three capacitors C_1, C_2 and C_3 are V_1, V_2 and V_3 respectively. So, we can write

$$\frac{V_2}{V_3} = \frac{C_3}{C_2} \qquad \text{....(1)}$$

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Since, Voltage is inversely proportional to capacitance
Now, given that

$$C_1 = 10\,\mu F\,;\ (V_1)_{\max} = 10\text{V}$$
$$C_2 = 5\,\mu F\,;\ (V_2)_{\max} = 5\text{ V}$$
$$C_3 = 2\,\mu F\,;\ (V_3)_{\max} = 2\text{V}$$

So, from Eq (1) we have

$$\frac{V_2}{V_3} = \frac{2}{5}$$

for $(V_3)_{\max} = 2$
We obtain,

$$V_2 = \frac{2 \times 2}{5} = 0.8 \text{ volt} < 5$$

i.e., $V_2 < (V_2)_{\max}$
Hence, this is the voltage at C_2. Therefore,

$$V_3 = 2 \text{ volt}$$
$$V_2 = 0.8 \text{ volt}$$

and $V_1 = V_2 + V_3 = 2.8$ volt
Now, equivalent capacitance across the terminal is

$$C_{eq} = \frac{C_2 C_3}{C_2 + C_3} + C_1$$
$$= \frac{5 \times 2}{5+2} + 10$$
$$= \frac{80}{7}\,\mu\text{F}$$

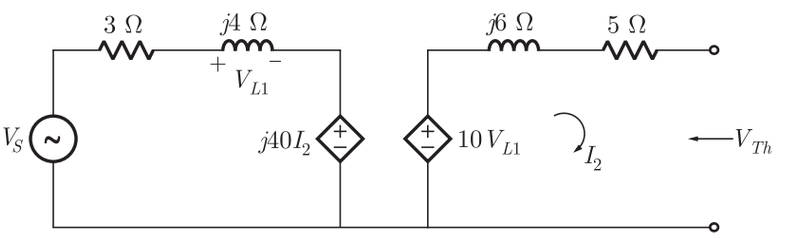
Equivalent voltage is (max. value)

$$V_{\max} = V_1 = 2.8$$

So, charge stored in the effective capacitance is

$$Q = C_{eq} V_{\max}$$
$$= \left(\frac{80}{7}\right) \times (2.8)$$
$$= 32\,\mu\text{C}$$

SOL 1.2.8 Option (C) is correct.
For evaluating the equivalent thevenin voltage seen by the load R_L, we open the circuit across it (also if it consist dependent source).
The equivalent circuit is shown below



As the circuit open across R_L so

$$I_2 = 0$$

or, $j40 I_2 = 0$
i.e., the dependent source in loop 1 is short circuited. Therefore,

$$V_{L1} = \frac{(j4)V_s}{j4+3}$$

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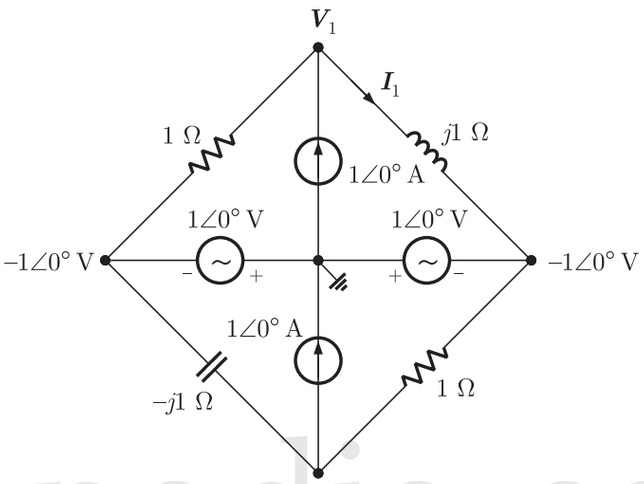
$$V_{Th} = 10V_{L1} = \frac{j40}{j4+3}100\angle 53.13^\circ$$
$$= \frac{40\angle 90^\circ}{5\angle 53.13^\circ}100\angle 53.13^\circ$$
$$= 800\angle 90^\circ$$

SOL 1.2.9 Option (C) is correct.



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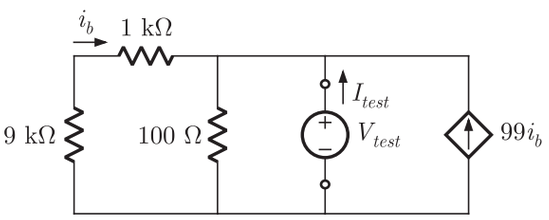
Applying nodal analysis at top node.

$$\frac{V_1 + 1\angle 0^\circ}{1} + \frac{V_1 + 1\angle 0^\circ}{j1} = 1\angle 0^\circ$$
$$V_1(j1+1) + j1 + 1\angle 0^\circ = j1$$
$$V_1 = \frac{-1}{1+j1}$$

Current $$I_1 = \frac{V_1 + 1\angle 0^\circ}{j1} = \frac{-\frac{1}{1+j} + 1}{j1} = \frac{j}{(1+j)j} = \frac{1}{1+j}\text{ A}$$

SOL 1.2.10 Option (A) is correct.

We put a test source between terminal 1, 2 to obtain equivalent impedance



$$Z_{Th} = \frac{V_{test}}{I_{test}}$$

By applying KCL at top right node

$$\frac{V_{test}}{9\text{k}+1\text{k}} + \frac{V_{test}}{100} - 99I_b = I_{test}$$
$$\frac{V_{test}}{10\text{k}} + \frac{V_{test}}{100} - 99I_b = I_{test} \quad \ldots(\text{i})$$

But $$I_b = -\frac{V_{test}}{9k+1k} = -\frac{V_{test}}{10\text{k}}$$

Substituting I_b into equation (i), we have

$$\frac{V_{test}}{10\text{k}} + \frac{V_{test}}{100} + \frac{99V_{test}}{10\text{k}} = I_{test}$$

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$$\frac{100V_{test}}{10\times10^3}+\frac{V_{test}}{100}=I_{test}$$

$$\frac{2V_{test}}{100}=I_{test}$$

$$Z_{Th}=\frac{V_{test}}{I_{test}}=50\,\Omega$$

SOL 1.2.11 Option (C) is correct.

$$G(s)=\frac{(s^2+9)(s+2)}{(s+1)(s+3)(s+4)}$$

$$G(j\omega)=\frac{(-\omega^2+9)(j\omega+2)}{(j\omega+1)(j\omega+3)(j\omega+4)}$$

The steady state output will be zero if

$$|G(j\omega)|=0$$

$$-\omega^2+9=0$$

$$\omega=3\,\text{rad/s}$$

SOL 1.2.12 Option (B) is correct.

In phasor form

$$Z=4-j3$$

$$Z=5\angle-36.86^\circ\,\Omega$$

$$I=5\angle100^\circ\,\text{A}$$

Average power delivered.

$$P_{avg.}=\frac{1}{2}|I|^2Z\cos\theta=\frac{1}{2}\times25\times5\cos36.86^\circ=50\,\text{W}$$

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Alternate method:

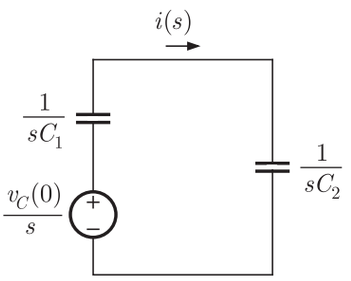
$$Z=(4-j3)\,\Omega$$

$$I=5\cos(100\pi t+100)\,\text{A}$$

$$P_{avg}=\frac{1}{2}\text{Re}\{|I|^2Z\}=\frac{1}{2}\times\text{Re}\{(5)^2\times(4-j3)\}=\frac{1}{2}\times100=50\,\text{W}$$

SOL 1.2.13 Option (D) is correct.

The s-domain equivalent circuit is shown as below.



$$I(s)=\frac{v_c(0)/s}{\frac{1}{C_1s}+\frac{1}{C_2s}}=\frac{v_c(0)}{\frac{1}{C_1}+\frac{1}{C_2}}$$

$$I(s)=\left(\frac{C_1C_2}{C_1+C_2}\right)(12\,\text{V}) \qquad v_C(0)=12\,\text{V}$$

$$I(s)=12C_{eq}$$

Taking inverse Laplace transform for the current in time domain,

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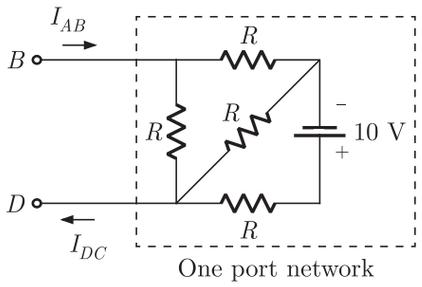
$$i(t) = 12C_{eq}\delta(t) \qquad \text{(Impulse)}$$

SOL 1.2.14 Option (A) is correct.

In the given circuit, $V_A - V_B = 6\text{ V}$

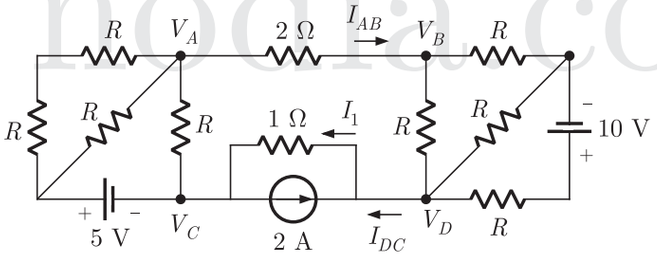
So current in the branch, $I_{AB} = \dfrac{6}{2} = 3\text{ A}$

We can see, that the circuit is a one port circuit looking from terminal BD as shown below



For a one port network current entering one terminal, equals the current leaving the second terminal. Thus the outgoing current from A to B will be equal to the incoming current from D to C as shown

i.e. $I_{DC} = I_{AB} = 3\text{ A}$



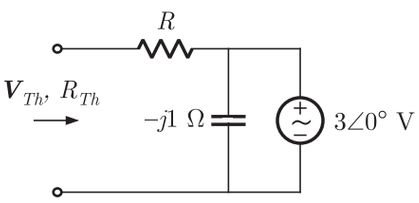
The total current in the resistor $1\,\Omega$ will be

$$I_1 = 2 + I_{DC} \qquad \text{(By writing KCL at node } D\text{)}$$
$$= 2 + 3 = 5\text{ A}$$

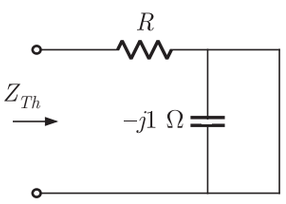
So, $V_{CD} = 1 \times (-I_1) = -5\text{ V}$

SOL 1.2.15 Option (A) is correct.

We obtain Thevenin equivalent of circuit B.



Thevenin Impedance :



$$Z_{Th} = R$$

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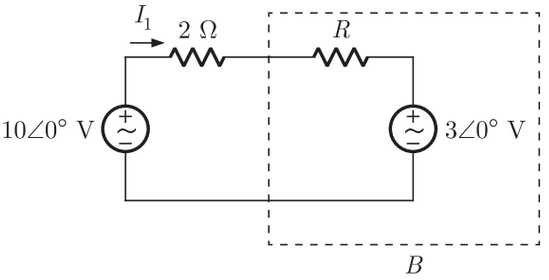
Thevenin Voltage :

$$V_{Th} = 3\angle 0^\circ \text{ V}$$

Now, circuit becomes as



Current in the circuit, $I_1 = \dfrac{10-3}{2+R}$

Power transfer from circuit A to B

$$P = (I_1^2)^2 R + 3I_1$$

$$= \left[\frac{10-3}{2+R}\right]^2 R + 3\left[\frac{10-3}{2+R}\right] = \frac{49R}{(2+R)^2} + \frac{21}{(2+R)}$$

$$= \frac{49R + 21(2+R)}{(2+R)^2} = \frac{42+70R}{(2+R)^2}$$

$$\frac{dP}{dR} = \frac{(2+R)^2 70 - (42+70R)2(2+R)}{(2+R)^4} = 0$$

$$(2+R)[(2+R)70 - (42+70R)2] = 0$$

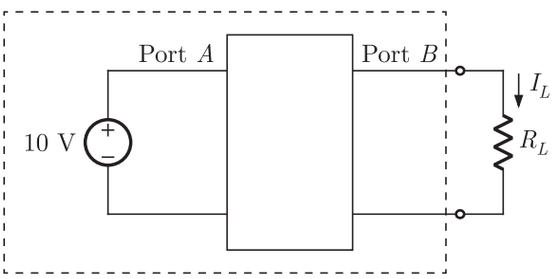
$$140 + 70R - 84 - 140R = 0$$

$$56 = 70R$$

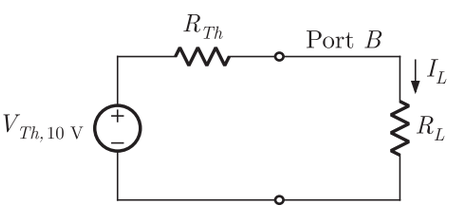
$$R = 0.8\,\Omega$$

SOL 1.2.16 Option (C) is correct.

When 10 V is connected at port A the network is



Now, we obtain Thevenin equivalent for the circuit seen at load terminal, let Thevenin voltage is $V_{Th,10\,\text{V}}$ with 10 V applied at port A and Thevenin resistance is R_{Th}.



$$I_L = \frac{V_{Th,10\,\text{V}}}{R_{Th} + R_L}$$

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For $R_L = 1\,\Omega$, $I_L = 3\,\text{A}$

$$3 = \frac{V_{Th,10\,\text{V}}}{R_{Th}+1} \qquad \text{...(i)}$$

For $R_L = 2.5\,\Omega$, $I_L = 2\,\text{A}$

$$2 = \frac{V_{Th,10\,\text{V}}}{R_{Th}+2.5} \qquad \text{...(ii)}$$

Dividing above two

$$\frac{3}{2} = \frac{R_{Th}+2.5}{R_{Th}+1}$$

$$3R_{Th}+3 = 2R_{Th}+5$$

$$R_{Th} = 2\,\Omega$$

Substituting R_{Th} into equation (i)

$$V_{Th,10\,\text{V}} = 3(2+1) = 9\,\text{V}$$

Note that it is a non reciprocal two port network. Thevenin voltage seen at port B depends on the voltage connected at port A. Therefore we took subscript $V_{Th,10\,\text{V}}$. This is Thevenin voltage only when 10 V source is connected at input port A. If the voltage connected to port A is different, then Thevenin voltage will be different. However, Thevenin's resistance remains same.

Now, the circuit is

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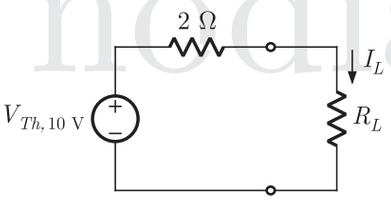
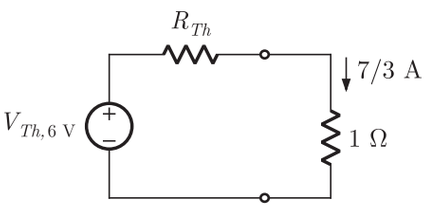


For $R_L = 7\,\Omega$, $\quad I_L = \dfrac{V_{Th,10\,\text{V}}}{2+R_L} = \dfrac{9}{2+7} = 1\,\text{A}$

SOL 1.2.17 Option (B) is correct.

Now, when 6 V connected at port A let Thevenin voltage seen at port B is $V_{Th,6\,\text{V}}$. Here $R_L = 1\,\Omega$ and $I_L = \dfrac{7}{3}\,\text{A}$



$$V_{Th,6\,\text{V}} = R_{Th} \times \frac{7}{3} + 1 \times \frac{7}{3} = 2 \times \frac{7}{3} + \frac{7}{3} = 7\,\text{V}$$

This is a linear network, so V_{Th} at port B can be written as

$$V_{Th} = V_1\alpha + \beta$$

where V_1 is the input applied at port A.

We have $V_1 = 10\,\text{V}$, $V_{Th,10\,\text{V}} = 9\,\text{V}$

$$9 = 10\alpha + \beta \qquad \text{...(i)}$$

When $V_1 = 6\,\text{V}$, $V_{Th,6\,\text{V}} = 9\,\text{V}$

$$7 = 6\alpha + \beta \qquad \text{...(ii)}$$

Solving (i) and (ii)

$$\alpha = 0.5,\ \beta = 4$$

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Thus, with any voltage V_1 applied at port A, Thevenin voltage or open circuit voltage at port B will be

So, $$V_{Th,V_1} = 0.5V_1 + 4$$

For $$V_1 = 8\,\text{V}$$

$$V_{Th,8\,\text{V}} = 0.5 \times 8 + 4 = 8 = V_{oc} \qquad \text{(open circuit voltage)}$$

SOL 1.2.18 Option (A) is correct.

By taking V_1, V_2 and V_3 all are phasor voltages.

$$V_1 = V_2 + V_3$$

Magnitude of V_1, V_2 and V_3 are given as

$$V_1 = 220\,\text{V}, V_2 = 122\,\text{V}, V_3 = 136\,\text{V}$$

Since voltage across R is in same phase with V_1 and the voltage V_3 has a phase difference of θ with voltage V_1, we write in polar form

$$V_1 = V_2 \angle 0^\circ + V_3 \angle \theta$$

$$V_1 = V_2 + V_3\cos\theta + jV_3\sin\theta$$

$$V_1 = (V_2 + V_3\cos\theta) + jV_3\sin\theta$$

$$|V_1| = \sqrt{(V_2 + V_3\cos\theta)^2 + (V_2\sin\theta)^2}$$

$$220 = \sqrt{(122 + 136\cos\theta)^2 + (136\sin\theta)^2}$$

By solving, power factor

$$\cos\theta = 0.45$$

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SOL 1.2.19 Option (B) is correct.

Voltage across load resistance

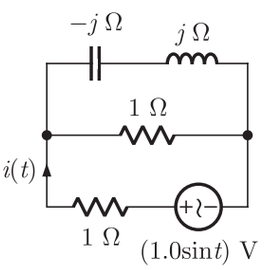
$$V_{RL} = V_3\cos\theta = 136 \times 0.45 = 61.2\,\text{V}$$

Power absorbed in R_L

$$P_L = \frac{V_{RL}^2}{R_L} = \frac{(61.2)^2}{5} \simeq 750\,\text{W}$$

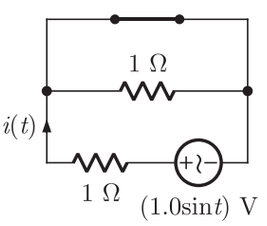
SOL 1.2.20 Option (B) is correct.

The frequency domains equivalent circuit at $\omega = 1\,\text{rad/sec}$.



Since the capacitor and inductive reactances are equal in magnitude, the net impedance of that branch will become zero.

Equivalent circuit



Current $$i(t) = \frac{\sin t}{1\,\Omega} = (1\sin t)\,\text{A}$$

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rms value of current

$$i_{\text{rms}} = \frac{1}{\sqrt{2}}\,\text{A}$$

SOL 1.2.21 Option (D) is correct.

Voltage in time domain

$$v(t) = 100\sqrt{2}\cos(100\pi t)$$

Current in time domain

$$i(t) = 10\sqrt{2}\sin(100\pi t + \pi/4)$$

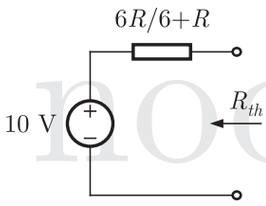
Applying the following trigonometric identity

$$\sin(\phi) = \cos(\phi - 90^\circ)$$

So,
$$i(t) = 10\sqrt{2}\cos(100\pi t + \pi/4 - \pi/2)$$
$$= 10\sqrt{2}\cos(100\pi t - \pi/4)$$

In phasor form, $I = \frac{10\sqrt{2}}{\sqrt{2}}\angle -\pi/4$

SOL 1.2.22 Option (A) is correct.



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Power transferred to the load

$$P = I^2 R_L = \left(\frac{10}{R_{th} + R_L}\right)^2 R_L$$

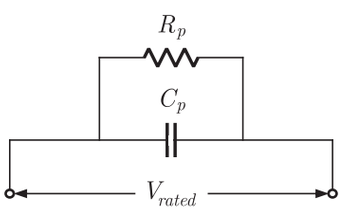
For maximum power transfer R_{th}, should be minimum.

$$R_{th} = \frac{6R}{6+R} = 0$$

$$R = 0$$

Note: Since load resistance is constant so we choose a minimum value of R_{th}

SOL 1.2.23 Option (C) is correct.



$$\text{Power loss} = \frac{V_{rated}^2}{R_p} = \frac{(5\times 10^3)^2}{1.25\times 10^6} = 20\ \text{W}$$

For an parallel combination of resistance and capacitor

$$\tan\delta = \frac{1}{\omega C_p R_p} = \frac{1}{2\pi \times 50 \times 1.25 \times 0.102} = \frac{1}{40} = 0.025$$

SOL 1.2.24 Option (C) is correct.

Charge

$$Q = CV = \frac{\varepsilon_0\varepsilon_r A}{d}V = (\varepsilon_0\varepsilon_r A)\frac{V}{d} \qquad C = \frac{\varepsilon_0\varepsilon_r A}{d}$$

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$$Q = Q_{\max}$$

We have $\varepsilon_0 = 8.85 \times 10^{-14}\,\text{F/cm}$, $\varepsilon_r = 2.26$, $A = 20 \times 40\,\text{cm}^2$

$$\frac{V}{d} = 50 \times 10^3\,\text{kV/cm}$$

Maximum electrical charge on the capacitor

when $$\frac{V}{d} = \left(\frac{V}{d}\right)_{\max} = 50\,\text{kV/cm}$$

Thus, $$Q = 8.85 \times 10^{-14} \times 2.26 \times 20 \times 40 \times 50 \times 10^3 = 8\,\mu\text{C}$$

SOL 1.2.25 Option (C) is correct.

$$v_i = 100\sqrt{2}\sin(100\pi t)\,\text{V}$$

Fundamental component of current

$$i_{i_1} = 10\sqrt{2}\sin(100\pi t - \pi/3)\,\text{A}$$

Input power factor

$$pf = \frac{I_{1(rms)}}{I_{rms}}\cos\phi_1$$

$I_{1(rms)}$ is rms values of fundamental component of current and I_{rms} is the rms value of converter current.

$$pf = \frac{10}{\sqrt{10^2 + 5^2 + 2^2}}\cos\pi/3 = 0.44$$

SOL 1.2.26 Option (B) is correct.

Only the fundamental component of current contributes to the mean ac input power. The power due to the harmonic components of current is zero.

So, $$P_{\text{in}} = V_{rms} I_{1rms}\cos\phi_1 = 100 \times 10\cos\pi/3 = 500\,\text{W}$$

SOL 1.2.27 Option (B) is correct.

Power delivered by the source will be equal to power dissipated by the resistor.

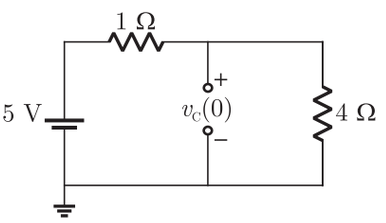
$$P = V_s I_s \cos\pi/4 = 1 \times \sqrt{2}\cos\pi/4 = 1\,\text{W}$$

SOL 1.2.28 Option (D) is correct.

$$\begin{aligned}\overline{I_C} &= \overline{I}_s - \overline{I}_{RL} = \sqrt{2}\underline{/\pi/4} - \sqrt{2}\underline{/-\pi/4} \\ &= \sqrt{2}\left\{(\cos\pi/4 + j\sin\pi/4) - (\cos\pi/4 - j\sin\pi/4)\right\} \\ &= 2\sqrt{2}\,j\sin\pi/4 = 2j\end{aligned}$$

SOL 1.2.29 Option (B) is correct.

For $t < 0$, the switch was closed for a long time so equivalent circuit is



Voltage across capacitor at $t = 0$

$$v_c(0) = \frac{5}{4 \times 1} = 4\ \text{V}$$

Now switch is opened, so equivalent circuit is

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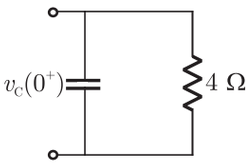


For capacitor at $t = 0^+$

$$v_c(0^+) = v_c(0) = 4 \text{ V}$$

current in 4 Ω resistor at $t = 0^+$, $i_1 = \dfrac{v_c(0^+)}{4} = 1$ A

so current in capacitor at $t = 0^+$, $i_c(0^+) = i_1 = 1$ A

SOL 1.2.30 Option (B) is correct.

Thevenin equivalent across 1 Ω resistor can be obtain as following

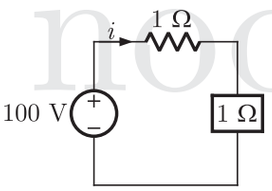
Open circuit voltage $v_{th} = 100$ V $(i = 0)$

Short circuit current $i_{sc} = 100$ A $(v_{th} = 0)$

So,

$$R_{th} = \frac{v_{th}}{i_{sc}} = \frac{100}{100} = 1\,\Omega$$

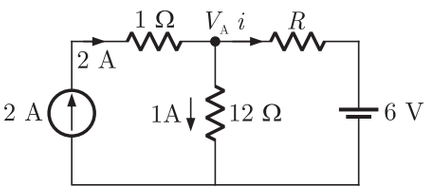
Equivalent circuit is



$$i = \frac{100}{1+1} = 50 \text{ A}$$

SOL 1.2.31 Option (B) is correct.

The circuit is



Current in $R\,\Omega$ resistor is

$$i = 2 - 1 = 1 \text{ A}$$

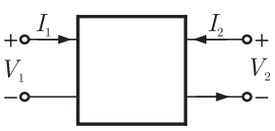
Voltage across 12 Ω resistor is

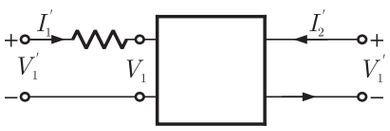
$$V_A = 1 \times 12 = 12 \text{ V}$$

So,

$$i = \frac{V_A - 6}{R} = \frac{12 - 6}{1} = 6\,\Omega$$

SOL 1.2.32 Option (C) is correct.





$V_1 = Z_{11}I_1 + Z_{12}I_2$ $\qquad$ $V'_1 = Z'_{11}I'_1 + Z'_{12}I'_2$

$V_2 = Z_{21}I_1 + Z_{22}I_2$ $\qquad$ $V'_2 = Z'_{21}I'_1 + Z'_{22}I'_2$

Here, $I_1 = I'_1$, $I_2 = I'_2$

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When $R = 1\,\Omega$ is connected

$$V'_1 = V_1 + I'_1 \times 1 = V_1 + I_1$$
$$V'_1 = Z_{11}I_1 + Z_{12}I_2 + I_1$$
$$V'_1 = (Z_{11} + 1)I_1 + Z_{12}I_2$$

So, $Z'_{11} = Z_{11} + 1$

$$Z'_{12} = Z_{12}$$

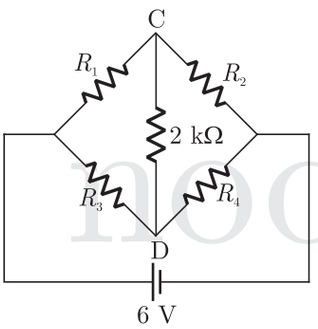
Similarly for output port

$$V'_2 = Z'_{21}I'_1 + Z'_{22}I'_2$$
$$= Z'_{21}I_1 + Z'_{22}I_2$$

So, $Z'_{21} = Z_{21}$, $Z'_{22} = Z_{22}$

Z-matrix is $$Z = \begin{bmatrix} Z_{11}+1 & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

SOL 1.2.33 Option (A) is correct.



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In the bridge

$$R_1R_4 = R_2R_3 = 1$$

So it is a balanced bridge

$$I = 0 \text{ mA}$$

SOL 1.2.34 Option (D) is correct.

Resistance of the bulb rated 200 W/220 V is

$$R_1 = \frac{V^2}{P_1} = \frac{(220)^2}{200} = 242\,\Omega$$

Resistance of 100 W/220 V lamp is

$$R_T = \frac{V^2}{P_2} = \frac{(220)^2}{100} = 484\,\Omega$$

To connect in series

$$R_T = n \times R_1$$
$$484 = n \times 242$$
$$n = 2$$

SOL 1.2.35 Option (D) is correct.

For $t < 0$, S_1 is closed and S_2 is opened so the capacitor C_1 will charged upto 3 volt.

$$V_{C1}(0) = 3 \text{ Volt}$$

Now when switch positions are changed, by applying charge conservation

$$C_{eq}V_{C_1}(0^+) = C_1V_{C_1}(0^+) + C_2V_{C_2}(0^+)$$
$$(2+1) \times 3 = 1 \times 3 + 2 \times V_{C_2}(0^+)$$

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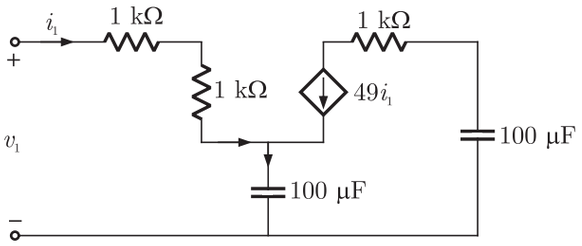
$$9 = 3 + 2V_{C_2}(0^+)$$

$$V_{C_2}(0^+) = 3 \text{ Volt}$$

SOL 1.2.36 Option (A) is correct.



Applying KVL in the input loop

$$v_1 - i_1(1+1) \times 10^3 - \frac{1}{j\omega C}(i_1 + 49i_1) = 0$$

$$v_1 = 2 \times 10^3 i_1 + \frac{1}{j\omega C} 50 i_1$$

Input impedance, $Z_1 = \frac{v_1}{i_1} = 2 \times 10^3 + \frac{1}{j\omega(C/50)}$

Equivalent capacitance, $C_{eq} = \frac{C}{50} = \frac{100\ \mu F}{50} = 2\ \mu F$

SOL 1.2.37 Option (B) is correct.

Voltage across 2 Ω resistor, $V_S = 2$ V

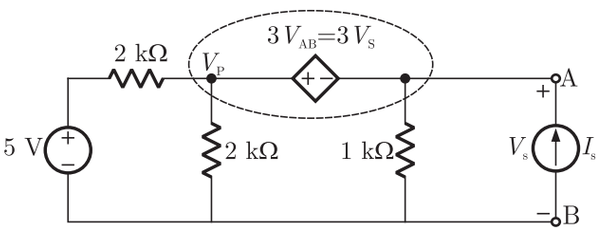
Current, $I_{2\Omega} = \frac{V_S}{2} = \frac{4}{2} = 2$ A

To make the current double we have to take

$$V_S = 8 \text{ V}$$

SOL 1.2.38 Option (B) is correct.

To obtain equivalent Thevenin circuit, put a test source between terminals AB



Applying KCL at super node

$$\frac{V_P - 5}{2} + \frac{V_P}{2} + \frac{V_S}{1} = I_S$$

$$V_P - 5 + V_P + 2V_S = 2I_S$$

$$2V_P + 2V_S = 2I_s + 5$$

$$V_P + V_S = I_S + 2.5 \quad \ldots(1)$$

$$V_P - V_S = 3V_S$$

$$\Rightarrow \quad V_P = 4V_S$$

So, $4V_S + V_S = I_S + 2.5$

$$5V_S = I_S + 2.5$$

$$V_S = 0.2I_S + 0.5 \quad \ldots(2)$$

For Thevenin equivalent circuit

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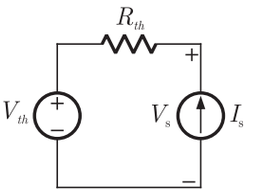

$$V_S = I_S R_{th} + V_{th} \qquad ...(3)$$

By comparing (2) and (3),

Thevenin resistance $R_{th} = 0.2\,\text{k}\Omega$

SOL 1.2.39 Option (D) is correct.

From above $V_{th} = 0.5\ \text{V}$

SOL 1.2.40 Option (A) is correct.

No. of chords is given as

$$l = b - n + 1$$

$b \rightarrow$ no. of branches

$n \rightarrow$ no. of nodes

$l \rightarrow$ no. of chords

$b = 6,\ n = 4$

$$l = 6 - 4 + 1 = 3$$

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SOL 1.2.41 Option (A) is correct.

Impedance $Z_o = 2.38 - j0.667\,\Omega$

Constant term in impedance indicates that there is a resistance in the circuit.

Assume that only a resistance and capacitor are in the circuit, phase difference in Thevenin voltage is given as

$$\theta = -\tan^{-1}(\omega CR) \qquad \text{(Due to capacitor)}$$

$$Z_o = R - \frac{j}{\omega C}$$

So, $\dfrac{1}{\omega C} = 0.667$

and $R = 2.38\,\Omega$

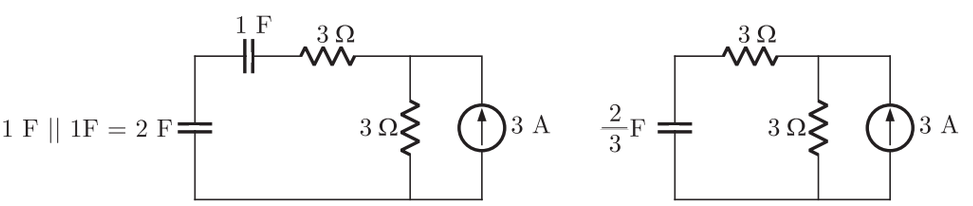
$$\theta = -\tan^{-1}\left(\frac{1 \times 2.38}{0.667}\right) = -74.34^\circ \neq -15.9^\circ$$

given $V_{oc} = 3.71 \angle -15.9^\circ$

So, there is an inductor also connected in the circuit

SOL 1.2.42 Option (C) is correct.

Time constant of the circuit can be calculated by simplifying the circuit as follows



$$C_{eq} = \frac{2}{3}\ \text{F}$$

Equivalent Resistance

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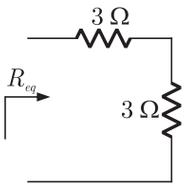


$$R_{eq} = 3 + 3 = 6\,\Omega$$

Time constant $\tau = R_{eq} C_{eq} = 6 \times \frac{2}{3} = 4$ sec

SOL 1.2.43 Option (C) is correct.

Impedance of the circuit is

$$Z = j\omega L + \frac{\frac{1}{j\omega C} R}{\frac{1}{j\omega C} + R} = j\omega L + \frac{R}{1 + j\omega CR} \times \frac{1 - j\omega CR}{1 - j\omega CR}$$

$$= j\omega L + \frac{R(1 - j\omega CR)}{1 + \omega^2 C^2 R^2} = \frac{j\omega L(1 + \omega^2 C^2 R^2) + R - j\omega CR^2}{1 + \omega^2 C^2 R^2}$$

$$= \frac{R}{1 + \omega^2 C^2 R^2} + \frac{j[\omega L(1 + \omega^2 C^2 R^2) - \omega CR^2]}{1 + \omega^2 C^2 R^2}$$

For resonance $\text{Im}(Z) = 0$

So, $\omega L(1 + \omega^2 C^2 R^2) = \omega CR^2$

$L = 0.1$ H, $C = 1$ F, $R = 1\,\Omega$

So, $\omega \times 0.1[1 + \omega^2 (1)(1)] = \omega (1)(1)^2$

$1 + \omega^2 = 10$

& $\omega = \sqrt{9} = 3$ rad/sec

SOL 1.2.44 Option (A) is correct.

By applying KVL in the circuit

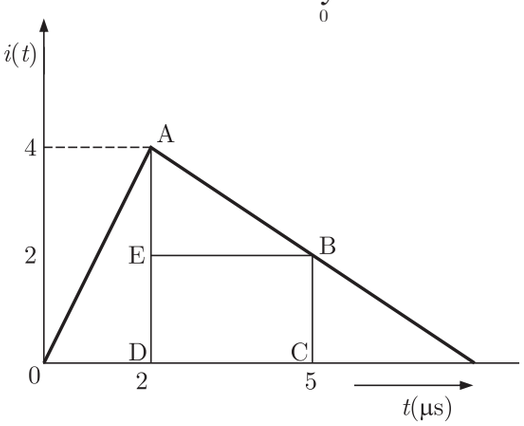
$V_{ab} - 2i + 5 = 0$

$i = 1$ A, $V_{ab} = 2 \times 1 - 5 = -3$ Volt

SOL 1.2.45 Option (C) is correct.

Charge stored at $t = 5\,\mu$ sec

$$Q = \int_0^5 i(t)\,dt = \text{area under the curve}$$



Q =Area OABCDO

=Area (OAD)+Area(AEB)+Area(EBCD)

$= \frac{1}{2} \times 2 \times 4 + \frac{1}{2} \times 2 \times 3 + 3 \times 2$

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$$= 4 + 3 + 6 = 13 \text{ nC}$$

SOL 1.2.46 Option (D) is correct.

Initial voltage across capacitor

$$V_0 = \frac{Q_o}{C} = \frac{13\,\text{nC}}{0.3\,\text{nF}} = 43.33 \text{ Volt}$$

When capacitor is connected across an inductor it will give sinusoidal esponse as

$$v_c(t) = V_o \cos \omega_o t$$

where $$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.3 \times 10^{-9} \times 0.6 \times 10^{-3}}}$$

$$= 2.35 \times 10^6 \text{ rad/sec}$$

At $t = 1\,\mu\text{sec}$, $v_c(t) = 43.33 \cos(2.35 \times 10^6 \times 1 \times 10^{-6})$

$$= 43.33 \times (-0.70) = -30.44 \text{ V}$$

SOL 1.2.47 Option (B) is correct.

By writing node equations at node A and B

$$\frac{V_a - 5}{1} + \frac{V_a - 0}{1} = 0$$

$$2V_a - 5 = 0$$

$$V_a = 2.5 \text{ V}$$

Similarly

$$\frac{V_b - 4V_{ab}}{3} + + \frac{V_b - 0}{1} = 0$$

$$\frac{V_b - 4(V_a - V_b)}{3} + V_b = 0$$

$$V_b - 4(2.5 - V_b) + 3V_b = 0$$

$$8V_b - 10 = 0$$

$$V_b = 1.25 \text{ V}$$

Current $$i = \frac{V_b}{1} = 1.25 \text{ A}$$

SOL 1.2.48 Option ( ) is correct.

SOL 1.2.49 Option (B) is correct.

Here two capacitance C_1 and C_2 are connected in series, so equivalent capacitance is

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

C_1	Glass	$\varepsilon_{r1} = 8;\ d_1 = 4$ mm
C_2	Paper	$\varepsilon_{r2} = 2;\ d_2 = 2$ mm

$$C_1 = \frac{\varepsilon_0 \varepsilon_{r1} A}{d_1} = \frac{8.85 \times 10^{-12} \times 8 \times 500 \times 500 \times 10^{-6}}{4 \times 10^{-3}}$$

$$= 442.5 \times 10^{-11} \text{ F}$$

$$C_2 = \frac{\varepsilon_0 \varepsilon_{r2} A}{d_2} = \frac{8.85 \times 10^{-12} \times 2 \times 500 \times 500 \times 10^{-6}}{2 \times 10^{-3}}$$

$$= 221.25 \times 10^{-11} \text{ F}$$

$$C_{eq} = \frac{442.5 \times 10^{-11} \times 221.25 \times 10^{-11}}{442.5 \times 10^{-11} + 221.25 \times 10^{-11}} = 147.6 \times 10^{-11}$$

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$\simeq 1476$ pF

SOL 1.2.50 Option (B) is correct.

Circumference $l = 300$ mm

no. of turns $n = 300$

Cross sectional area $A = 300\ \text{mm}^2$

Inductance of coil $L = \dfrac{\mu_0 n^2 A}{l} = \dfrac{4\pi \times 10^{-7} \times (300)^2 \times 300 \times 10^{-6}}{(300 \times 10^{-3})}$

$= 113.04\ \mu\text{H}$

SOL 1.2.51 Option (A) is correct.

Divergence of a vector field is given as

$\text{Divergence} = \nabla \cdot V$

In cartesian coordinates

$$\nabla = \frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}$$

So $\nabla \cdot V = \dfrac{\partial}{\partial x}[-(x\cos xy + y)] + \dfrac{\partial}{\partial y}[(y\cos xy)] + \dfrac{\partial}{\partial z}[(\sin z^2 + x^2 + y^2)]$

$= -x(-\sin xy)y + y(-\sin xy)x + 2z\cos z^2 = 2z\cos z^2$

SOL 1.2.52 Option (A) is correct.

Writing KVL for both the loops

$$V - 3(I_1 + I_2) - V_x - 0.5\frac{dI_1}{dt} = 0$$

$$V - 3I_1 - 3I_2 - V_x - 0.5\frac{dI_1}{dt} = 0 \qquad \ldots(1)$$

In second loop

$$-5I_2 + 0.2V_x + 0.5\frac{dI_1}{dt} = 0$$

$$I_2 = 0.04V_x + 0.1\frac{dI_1}{dt} \qquad \ldots(2)$$

Put I_2 from eq(2) into eq(2)

$$V - 3I_1 - 3\left[0.04V_x + 0.1\frac{dI_1}{dt}\right] - V_x - 0.5\frac{dI_1}{dt} = 0$$

$$0.8\frac{dI_1}{dt} = -1.12V_x - 3I_1 + V$$

$$\frac{dI_1}{dt} = -1.4V_x - 3.75I_1 + \frac{5}{4}V$$

SOL 1.2.53 Option (A) is correct.

Impedance of the given network is

$$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

$$\text{Admittance} Y = \frac{1}{Z} = \frac{1}{R + j\left(\omega L - \frac{1}{\omega C}\right)}$$

$$= \frac{1}{R + j\left(\omega L - \frac{1}{\omega C}\right)} \times \frac{R - j\left(\omega L - \frac{1}{\omega C}\right)}{R - j\left(\omega L - \frac{1}{\omega C}\right)} = \frac{R - j\left(\omega L - \frac{1}{\omega C}\right)}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$= \frac{R}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} - \frac{j\left(\omega L - \frac{1}{\omega C}\right)}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

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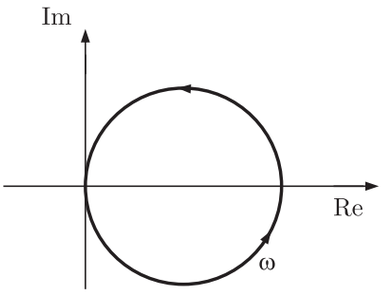
$$= \text{Re}(Y) + \text{Im}(Y)$$

Varying frequency for $\text{Re}(Y)$ and $\text{Im}(Y)$ we can obtain the admittance-locus.



SOL 1.2.54 Option (D) is correct.

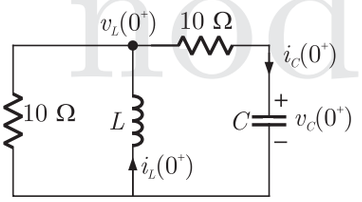
At $t = 0^+$, when switch positions are changed inductor current and capacitor voltage does not change simultaneously

So at $t = 0^+$

$$v_c(0^+) = v_c(0^-) = 10 \text{ V}$$

$$i_L(0^+) = i_L(0^-) = 10 \text{ A}$$

The equivalent circuit is



Applying KCL

$$\frac{v_L(0^+)}{10} + \frac{v_L(0^+) - v_c(0^+)}{10} = i_L(0^+) = 10$$

$$2v_L(0^+) - 10 = 100$$

Voltage across inductor at $t = 0^+$

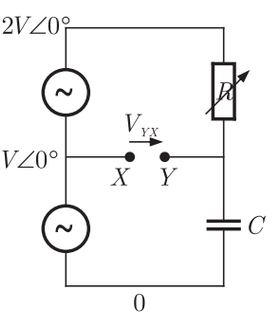
$$v_L(0^+) = \frac{100 + 10}{2} = 55 \text{ V}$$

So, current in capacitor at $t = 0^+$

$$i_C(0^+) = \frac{v_L(0^+) - v_c(0^+)}{10} = \frac{55 - 10}{10} = 4.5 \text{ A}$$

SOL 1.2.55 Option (B) is correct.

In the circuit



$$V_X = V\angle 0°$$

$$\frac{V_y - 2V\angle 0°}{R} + (V_y) j\omega C = 0$$

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$$V_y(1+j\omega CR) = 2V\angle 0^\circ$$

$$V_y = \frac{2V\angle 0^\circ}{1+j\omega CR}$$

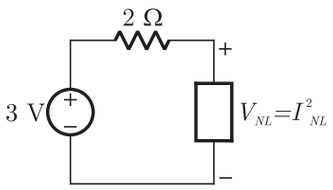
$$V_{YX} = V_X - V_Y = V - \frac{2V}{1+j\omega CR}$$

$R \to 0$, $\quad V_{YX} = V - 2V = -V$

$R \to \infty$, $\quad V_{YX} = V - 0 = V$

SOL 1.2.56 Option (A) is correct.

The circuit is



Applying KVL

$$3 - 2 \times I_{NL}^2 = V_{NL}$$

$$3 - 2I_{NL}^2 = I_{NL}^2$$

$$3I_{NL}^2 = 3 \;\&\; I_{NL} = 1 \text{ A}$$

$$V_{NL} = (1)^2 = 1 \text{ V}$$

So power dissipated in the non-linear resistance

$$P = V_{NL} I_{NL} = 1 \times 1 = 1 \text{ W}$$

SOL 1.2.57 Option (C) is correct.

In node incidence matrix

$$\begin{array}{c} \\ n_1 \\ n_2 \\ n_3 \\ n_4 \end{array} \begin{array}{c} \begin{array}{cccccc} b_1 & b_2 & b_3 & b_4 & b_5 & b_6 \end{array} \\ \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & 1 & 0 \\ -1 & 0 & 0 & 0 & -1 & -1 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{bmatrix} \end{array}$$

In option (C)

$$E = AV$$

$$\begin{bmatrix} e_1 & e_2 & e_3 & e_4 \end{bmatrix}^T = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & 1 & 0 \\ -1 & 0 & 0 & 0 & -1 & -1 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{bmatrix} \begin{bmatrix} V_1 & V_2 & -- & V_6 \end{bmatrix}^T$$

$$\begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix} = \begin{bmatrix} V_1 + V_2 + V_3 \\ -V_2 - V_4 + V_5 \\ -V_1 - V_5 - V_6 \\ -V_3 + V_4 + V_6 \end{bmatrix}$$ which is true.

SOL 1.2.58 Option (A) is correct.

Assume a Gaussian surface inside the sphere ($x < R$)

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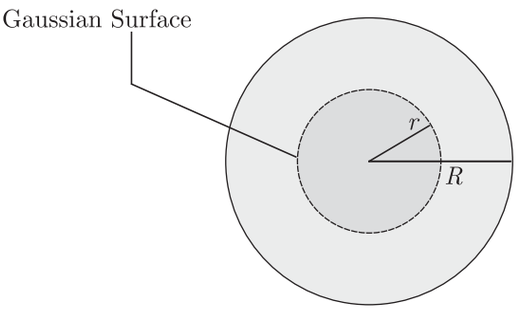


From gauss law

$$\psi = Q_{\text{enclosed}}$$
$$= \oint D \cdot ds = Q_{\text{enclosed}}$$
$$Q_{\text{enclosed}} = \frac{Q}{\frac{4}{3}\pi R^3} \times \frac{4}{3}\pi r^3 = \frac{Qr^3}{R^3}$$

So, $$\oint D \cdot ds = \frac{Qr^3}{R^3}$$

or $$D \times 4\pi r^2 = \frac{Qr^3}{R^3} = \frac{Q}{4\pi\varepsilon_0}\frac{r}{R^3} \qquad \because D = \varepsilon_0 E$$

SOL 1.2.59 Option (D) is correct.

Inductance is given as

$$L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi \times 10^{-7} \times (400)^2 \times (16 \times 10^{-4})}{(1 \times 10^{-3})} = 321.6\,\text{mH}$$

$$V = IX_L = \frac{230}{2\pi fL} \qquad \therefore X_L = 2\pi fL$$

$$= \frac{230}{2 \times 3.14 \times 50 \times 321.6 \times 10^{-3}} = 2.28\ \text{A}$$

SOL 1.2.60 Option (A) is correct.

Energy stored is inductor

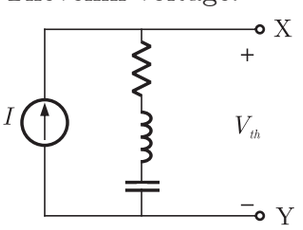
$$E = \frac{1}{2}LI^2 = \frac{1}{2} \times 321.6 \times 10^{-3} \times (2.28)^2$$

Force required to reduce the air gap of length 1 mm is

$$F = \frac{E}{l} = \frac{0.835}{1 \times 10^{-3}} = 835\ \text{N}$$

SOL 1.2.61 Option (D) is correct.

Thevenin voltage:



$$V_{th} = I(R + Z_L + Z_C) = 1\angle 0^\circ\,[1 + 2j - j]$$
$$= 1\,(1 + j) = \sqrt{2}\angle 45^\circ\ \text{V}$$

Thevenin impedance:

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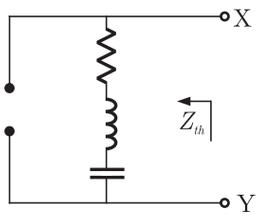
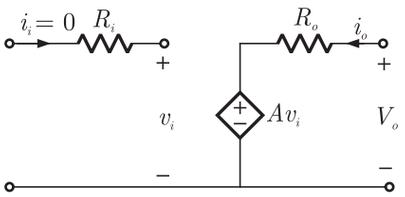


$$Z_{th} = R + Z_L + Z_C = 1 + 2j - j = (1 + j)\,\Omega$$

SOL 1.2.62 Option (A) is correct.

In the given circuit



Output voltage

$$v_o = Av_i = 10^6 \times 1\,\mu\text{V} = 1\text{ V}$$

Input impedance

$$Z_i = \frac{v_i}{i_i} = \frac{v_i}{0} = \infty$$

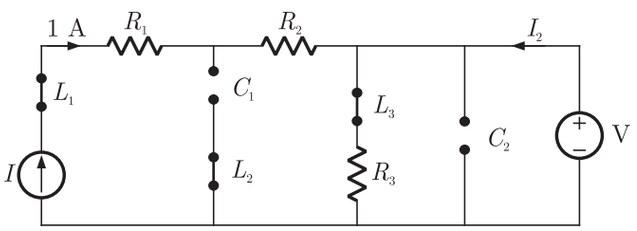
Output impedance

$$Z_o = \frac{v_o}{i_o} = \frac{Av_i}{i_o} = R_o = 10\,\Omega$$

SOL 1.2.63 Option (D) is correct.

All sources present in the circuit are DC sources, so all inductors behaves as short circuit and all capacitors as open circuit

Equivalent circuit is



Voltage across R_3 is

$$5 = I_1 R_3$$
$$5 = I_1(1)$$
$$I_1 = 5\text{ A} \qquad \text{(current through } R_3\text{)}$$

By applying KCL, current through voltage source

$$1 + I_2 = I_1$$
$$I_2 = 5 - 1 = 4\text{ A}$$

SOL 1.2.64 Option () is correct.

Given Two port network can be described in terms of h-parametrs only.

SOL 1.2.65 Option (A) is correct.

At resonance reactance of the circuit would be zero and voltage across inductor and capacitor would be equal

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$$V_L = V_C$$

At resonance impedance of the circuit

$$Z_R = R_1 + R_2$$

Current $$I_R = \frac{V_1 \angle 0^\circ}{R_1 + R_2}$$

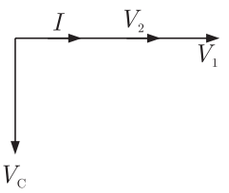
Voltage $$V_2 = I_R R_2 + j(V_L - V_C)$$

$$V_2 = \frac{V_1 \angle 0^\circ}{R_1 + R_2} R_2$$

Voltage across capacitor

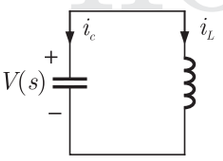
$$V_C = \frac{1}{j\omega C} \times I_R = \frac{1}{j\omega C} \times \frac{V_R \angle 0^\circ}{R_1 + R_2} = \frac{V_R \angle -90^\circ}{\omega C(R_1 + R_2)}$$

So phasor diagram is



SOL 1.2.66 Option (B) is correct.

This is a second order LC circuit shown below



Capacitor current is given as

$$i_C(t) = C\frac{dv_c(t)}{dt}$$

Taking Laplace transform

$$I_C(s) = CsV(s) - V(0),\ V(0) \rightarrow \text{initial voltage}$$

Current in inductor

$$i_L(t) = \frac{1}{L}\int v_c(t)\,dt$$

$$I_L(s) = \frac{1}{L}\frac{V(s)}{s}$$

for $t > 0$, applying KCL(in s-domain)

$$I_C(s) + I_L(s) = 0$$

$$CsV(s) - V(0) + \frac{1}{L}\frac{V(s)}{s} = 0$$

$$\left[s^2 + \frac{1}{LCs}\right]V(s) = V_o$$

$$V(s) = V_o \frac{s}{s^2 + \omega_0^2}, \qquad \because\ \omega_0^2 = \frac{1}{LC}$$

Taking inverse Laplace transformation

$$v(t) = V_o \cos\omega_o t, \quad t > 0$$

SOL 1.2.67 Option (B) is correct.

Power dissipated in heater when AC source is connected

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$$P = 2.3\,\text{kW} = \frac{V_{rms}^2}{R}$$

$$2.3 \times 10^3 = \frac{(230)^2}{R}$$

$$R = 23\,\Omega \text{ (Resistance of heater)}$$

Now it is connected with a square wave source of 400 V peak to peak

Power dissipated is

$$P = \frac{V_{rms}^2}{R}\ , \qquad V_{p-p} = 400\ \text{V} \Rightarrow V_p = 200\ \text{V}$$

$$= \frac{(200)^2}{23} = 1.739\ \text{kW} \qquad V_{rms} = V_p = 200 \quad \text{(for square wave)}$$

SOL 1.2.68 Option (D) is correct.

From maxwell's first equation

$$\nabla \cdot D = \rho_v$$

$$\nabla \cdot E = \frac{\rho_v}{\varepsilon}$$

(Divergence of electric field intensity is non-Zero)

Maxwell's fourth equation

$$\nabla \cdot B = 0$$

(Divergence of magnetic field intensity is zero)

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SOL 1.2.69 Option (C) is correct.

Current in the circuit

$$I = \frac{100}{R + (10\,||\,10)} = 8\ \text{A} \qquad \text{(given)}$$

$$\frac{100}{R+5} = 8$$

Or $$R = \frac{60}{8} = 7.5\,\Omega$$

SOL 1.2.70 Option (A) is correct.

Rms value is given as

$$\mu_{rms} = \sqrt{3^2 + \frac{(4)^2}{2}} = \sqrt{9+8} = \sqrt{17}\ \text{V}$$

SOL 1.2.71 Option (D) is correct.

Writing KVL in input and output loops

$$V_1 - (i_1 + i_2) Z_1 = 0$$

$$V_1 = Z_1 i_1 + Z_1 i_2 \qquad \ldots(1)$$

Similarly

$$V_2 - i_2 Z_2 - (i_1 + i_2) Z_1 = 0$$

$$V_2 = Z_1 i_1 + (Z_1 + Z_2) i_2 \qquad \ldots(2)$$

From equation (1) and (2) Z-matrix is given as

$$Z = \begin{bmatrix} Z_1 & Z_1 \\ Z_1 & Z_1 + Z_2 \end{bmatrix}$$

SOL 1.2.72 Option (B) is correct.

In final steady state the capacitor will be completely charged and behaves as an open circuit

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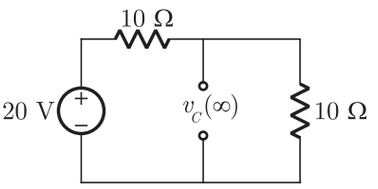


Steady state voltage across capacitor

$$v_c(\infty) = \frac{20}{10+10}(10) = 10 \text{ V}$$

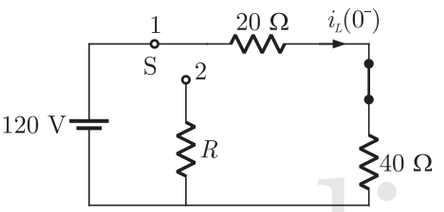
SOL 1.2.73 Option (D) is correct.

We know that divergence of the curl of any vector field is zero

$$\nabla\,(\nabla \times \vec{E}) = 0$$

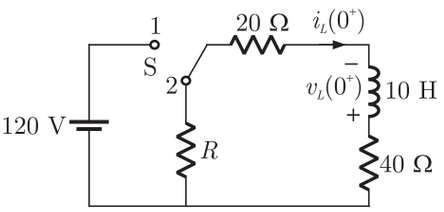
SOL 1.2.74 Option (A) is correct.

When the switch is at position 1, current in inductor is given as



$$i_L(0^-) = \frac{120}{20+40} = 2 \text{ A}$$

At $t = 0$, when switch is moved to position 1,inductor current does not change simultaneously so



$$i_L(0^+) = i_L(0^-) = 2 \text{ A}$$

Voltage across inductor at $t = 0^+$

$$v_L(0^+) = 120 \text{ V}$$

By applying KVL in loop

$$120 = 2(40 + R + 20)$$
$$120 = 120 + R$$
$$R = 0\,\Omega$$

SOL 1.2.75 Option (C) is correct.

Let stored energy and dissipated energy are E_1 and E_2 respectively. Then Current

$$\frac{i_2^2}{i_1^2} = \frac{E_2}{E_1} = 0.95$$
$$i_2 = \sqrt{0.95}\, i_1 = 0.97 i_1$$

Current at any time t, when the switch is in position (2) is given by

$$i(t) = i_1 e^{-\frac{R}{L}t} = 2e^{-\frac{60}{10}t} = 2e^{-6t}$$

After 95% of energy dissipated current remaining in the circuit is

$$i = 2 - 2 \times 0.97 = 0.05 \text{ A}$$

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So, $0.05 = 2e^{-6t}$

$t \approx 0.50$ sec

SOL 1.2.76 Option (C) is correct.

At $f_1 = 100$ Hz, voltage drop across R and L is μ_{RMS}

$$\mu_{RMS} = \left|\frac{V_{in}.R}{R + j\omega_1 L}\right| = \left|\frac{V_{in}(j\omega_1 L)}{R + j\omega_1 L}\right|$$

So, $R = \omega_1 L$

At $f_2 = 50$ Hz, voltage drop across R

$$\mu'_{RMS} = \left|\frac{V_{in}.R}{R + j\omega_2 L}\right|$$

$$\frac{\mu_{RMS}}{\mu'_{RMS}} = \left|\frac{R + j\omega_2 L}{R + j\omega_1 L}\right| = \sqrt{\frac{R^2 + \omega_2^2 L^2}{R^2 + \omega_1^2 L^2}}$$

$$= \sqrt{\frac{\omega_1^2 L^2 + \omega_2^2 L^2}{\omega_1^2 L^2 + \omega_1^2 L^2}}, \quad R = \omega_1 L$$

$$= \sqrt{\frac{\omega_1^2 + \omega_2^2}{2\omega_1^2}} = \sqrt{\frac{f_1^2 + f_2^2}{2f_1^2}} = \sqrt{\frac{(100)^2 + (50)^2}{2(100)^2}} = \sqrt{\frac{5}{8}}$$

$$\mu'_{RMS} = \sqrt{\frac{8}{5}}\,\mu_{RMS}$$

SOL 1.2.77 Option (A) is correct.

In the circuit

$$\bar{I}_B = I_R \angle 0^\circ + I_y \angle 120^\circ$$

$$I_B^2 = I_R^2 + I_y^2 + 2I_R I_y \cos\left(\frac{120^\circ}{2}\right) = I_R^2 + I_y^2 + I_R I_y$$

Since $I_R = I_y$

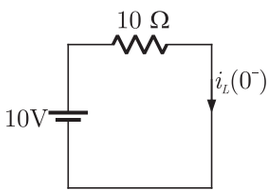
so, $I_B^2 = I_R^2 + I_R^2 + I_R^2 = 3I_R^2$

$I_B = \sqrt{3}\, I_R = \sqrt{3}\, I_y$

$I_R : I_y : I_B = 1 : 1 : \sqrt{3}$

SOL 1.2.78 Option (C) is correct.

Switch was opened before $t = 0$, so current in inductor for $t < 0$



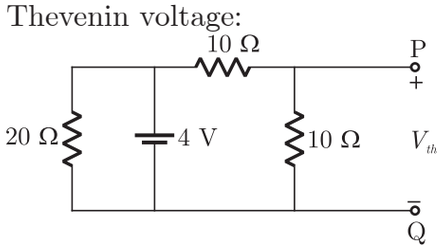
$$i_L(0^-) = \frac{10}{10} = 1 \text{ A}$$

Inductor current does not change simultaneously so at $t = 0$ when switch is closed current remains same

$$i_L(0^+) = i_L(0^-) = 1 \text{ A}$$

SOL 1.2.79 Option (A) is correct.

Thevenin voltage:



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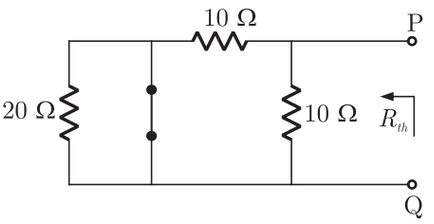
Nodal analysis at P

$$\frac{V_{th}-4}{10}+\frac{V_{th}}{10}=0$$

$$2V_{th}-4=0$$

$$V_{th}=2\text{ V}$$

Thevenin resistance:



$$R_{th}=10\,\Omega\,||\,10\,\Omega=5\,\Omega$$

SOL 1.2.80 Option (A) is correct.

Electric field inside a conductor (metal) is zero. In dielectric charge distribution os constant so electric field remains constant from x_1 to x_2. In semiconductor electric field varies linearly with charge density.

SOL 1.2.81 Option (D) is correct.

Resonance will occur only when Z is capacitive, in parallel resonance condition, suseptance of circuit should be zero.

$$\frac{1}{j\omega L}+j\omega C=0$$

$$1-\omega^2LC=0$$

$$\omega=\frac{1}{\sqrt{LC}}\text{ (resonant frequency)}$$

$$C=\frac{1}{\omega^2L}=\frac{1}{4\times\pi^2\times(500)^2\times2}=0.05\,\mu\text{F}$$

SOL 1.2.82 Option (D) is correct.

Here two capacitor C_1 and C_2 are connected in series so equivalent Capacitance is

$$C_{eq}=\frac{C_1C_2}{C_1+C_2}$$

$$C_1=\frac{\varepsilon_0\varepsilon_{r1}A}{d_1}=\frac{8.85\times10^{-12}\times4(400\times10^{-3})^2}{6\times10^{-3}}$$

$$=\frac{8.85\times10^{-12}\times4\times16\times10^{-2}}{6\times10^{-3}}=94.4\times10^{-11}\text{ F}$$

Similarly

$$C_2=\frac{\varepsilon_0\varepsilon_{r2}A}{d_2}=\frac{8.85\times10^{-12}\times2\times(400\times10^{-3})^2}{8\times10^{-3}}$$

$$=\frac{8.85\times10^{-12}\times2\times16\times10^{-12}}{8\times10^{-3}}=35.4\times10^{-11}\text{ F}$$

$$C_{eq}=\frac{94.4\times10^{-11}\times35.4\times10^{-11}}{(94.4+35.4)\times10^{-11}}=25.74\times10^{-11}\simeq257\text{ pF}$$

SOL 1.2.83 Option (C) is correct.

Inductance of the Solenoid is given as

$$L=\frac{\mu_0N^2A}{l}$$

Where $A\rightarrow$ are of Solenoid

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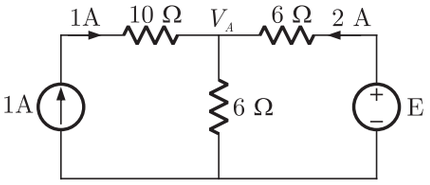
$l \rightarrow$ length

$$L = \frac{4\pi \times 10^{-7} \times (3000)^2 \times \pi (30 \times 10^{-3})^2}{(1000 \times 10^{-3})} = 31.94 \times 10^{-3} \text{ H}$$

$$\simeq 32 \text{ mH}$$

SOL 1.2.84 Option (C) is correct.

In the circuit



Voltage $V_A = (2+1) \times 6 = 18$ Volt

So, $2 = \dfrac{E - V_A}{6}$

$$2 = \frac{E - 18}{6}$$

$$E = 12 + 18 = 30 \text{ V}$$

SOL 1.2.85 Option (A) is correct.

Delta to star $(\Delta - Y)$ conversions is given as

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} = \frac{10 \times 10}{20 + 10 + 10} = 2.5\,\Omega$$

$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c} = \frac{20 \times 10}{20 + 10 + 10} = 5\,\Omega$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c} = \frac{20 \times 10}{20 + 10 + 10} = 5\,\Omega$$

SOL 1.2.86 Option (D) is correct.

For parallel circuit

$$I = \frac{E}{Z_{eq}} = E Y_{eq}$$

$Y_{eq} \rightarrow$ Equivalent admittance of the circuit

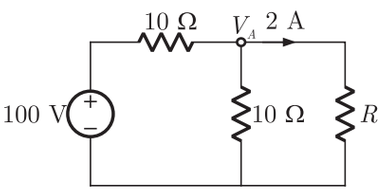
$$Y_{eq} = Y_R + Y_L + Y_C = (0.5 + j0) + (0 - j1.5) + (0 + j0.3)$$

$$= 0.5 - j1.2$$

So, current $I = 10(0.5 - j1.2) = (5 - j12)\,\text{A}$

SOL 1.2.87 Option (B) is correct.

In the circuit



Voltage $V_A = \dfrac{100}{10 + (10 \,||\, R)} \times (10 \,||\, R) = \left(\dfrac{100}{10 + \dfrac{10R}{10+R}}\right)\left(\dfrac{10R}{10+R}\right)$

$$= \frac{1000R}{100 + 20R} = \frac{50R}{5+R}$$

Current in $R\,\Omega$ resistor

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$$2 = \frac{V_A}{R}$$

$$2 = \frac{50R}{R(5+R)}$$

or $$R = 20\,\Omega$$

SOL 1.2.88 Option (A) is correct.

Since capacitor initially has a charge of 10 coulomb, therefore

$$Q_0 = Cv_c(0) \qquad v_c(0) \rightarrow \text{initial voltage across capacitor}$$

$$10 = 0.5v_c(0)$$

$$v_c(0) = \frac{10}{0.5} = 20 \text{ V}$$

When switch S is closed, in steady state capacitor will be charged completely and capacitor voltage is

$$v_c(\infty) = 100 \text{ V}$$

At any time t transient response is

$$v_c(t) = v_c(\infty) + [v_c(0) - v_c(\infty)]\,e^{-\frac{t}{RC}}$$

$$v_c(t) = 100 + (20 - 100)\,e^{-\frac{t}{2\times 0.5}} = 100 - 80e^{-t}$$

Current in the circuit

$$i(t) = C\frac{dv_c}{dt} = C\frac{d}{dt}[100 - 80e^{-t}]$$

$$= C \times 80e^{-t} = 0.5 \times 80e^{-t} = 40e^{-t}$$

At $t = 1$ sec,

$$i(t) = 40e^{-1} = 14.71 \text{ A}$$

SOL 1.2.89 Option (D) is correct.

Total current in the wire

$$I = 10 + 20\sin\omega t$$

$$I_{rms} = \sqrt{10^2 + \frac{(20)^2}{2}} = \sqrt{100 + 200} = \sqrt{300} = 17.32 \text{ A}$$

SOL 1.2.90 Option (D) is correct.

From Z to Y parameter conversion

$$\begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}^{-1}$$

So, $$\begin{bmatrix} Y_{11} & Y_{12} \\ Y_{12} & Y_{22} \end{bmatrix} = \frac{1}{0.50}\begin{bmatrix} 0.6 & -0.2 \\ -0.2 & 0.9 \end{bmatrix}$$

$$Y_{22} = \frac{0.9}{0.50} = 1.8$$

SOL 1.2.91 Option (C) is correct.

Energy absorbed by the inductor coil is given as

$$E_L = \int_0^t P\,dt$$

Where power $$P = VI = I\left(L\frac{dI}{dt}\right)$$

So, $$E_L = \int_0^t LI\left(\frac{dI}{dt}\right)dt$$

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For $0 \le t \le 4$ sec

$$E_L = 2\int_0^4 I\left(\frac{dI}{dt}\right)dt$$

$$= 2\int_0^2 I(3)\,dt + 2\int_2^4 I(0)\,dt \qquad \begin{cases} \because \frac{dI}{dt} = 3, 0 \le t \le 2 \\ \quad\;\; = 0, 2 < t < 4 \end{cases},$$

$$= 6\int_0^2 I.dt = 6(\text{area under the curve } i(t) - t)$$

$$= 6 \times \frac{1}{2} \times 2 \times 6 = 36 \text{ J}$$

Energy absorbed by $1\,\Omega$ resistor is

$$E_R = \int_0^t I^2 R dt$$

$$= \int_0^2 (3t)^2 \times 1dt + \int_2^4 (6)^2 dt \qquad \begin{cases} I = 3t, & 0 \le t \le 2 \\ = 6\text{ A} & 2 \le t \le 4 \end{cases}$$

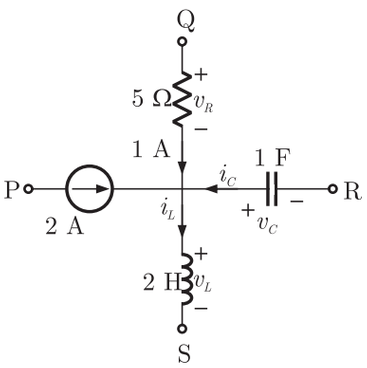
$$= 9 \times \left[\frac{t^3}{3}\right]_0^2 + 36\left[t\right]_2^4 = 24 + 72 = 96 \text{ J}$$

Total energy absorbed in 4 sec

$$E = E_L + E_R = 36 + 96 = 132 \text{ J}$$

SOL 1.2.92 Option (B) is correct.

Applying KCL at center node



$$i_L = i_C + 1 + 2$$

$$i_L = i_C + 3$$

$$i_C = -C\frac{dv_c}{dt} = -1\frac{d}{dt}[4\sin 2t]$$

$$= -8\cos 2t$$

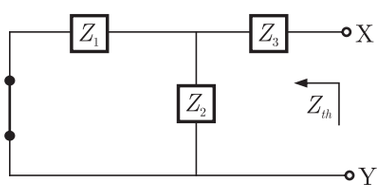
so $$i_L = -8\cos 2t + 3 \qquad \text{(current through inductor)}$$

Voltage across inductor

$$v_L = L\frac{di_L}{dt} = 2 \times \frac{d}{dt}[3 - 8\cos 2t] = 32\sin 2t$$

SOL 1.2.93 Option (A) is correct.

Thevenin impedance can be obtain as following



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$$Z_{th} = Z_3 + (Z_1 \,||\, Z_2)$$

Given that $Z_1 = 10\angle -60^\circ = 10\left(\frac{1-\sqrt{3}j}{2}\right) = 5(1-\sqrt{3}j)$

$$Z_2 = 10\angle 60^\circ = 10\left(\frac{1+\sqrt{3}j}{2}\right) = 5(1+\sqrt{3}j)$$

$$Z_3 = 50\angle 53.13^\circ = 50\left(\frac{3+4j}{5}\right) = 10(3+4j)$$

So, $$Z_{th} = 10(3+4j) + \frac{5(1-3j)\,5(1+\sqrt{3}j)}{5(1-\sqrt{3}j)+5(1+\sqrt{3}j)}$$

$$= 10(3+4j) + \frac{25(1+3)}{10} = 30+40j+10 = 40+40j$$

$$Z_{th} = 40\sqrt{2}\angle 45^\circ\,\Omega$$

SOL 1.2.94 Option (A) is correct.

Due to the first conductor carrying $+I$ current, magnetic field intensity at point P is

$$\vec{H_1} = \frac{I}{2\pi d}\vec{Y} \text{ (Direction is determined using right hand rule)}$$

Similarly due to second conductor carrying $-I$ current, magnetic field intensity is

$$\vec{H_2} = \frac{-I}{2\pi d}(-\vec{Y}) = \frac{I}{2\pi d}\vec{Y}$$

Total magnetic field intensity at point P.

$$\vec{H} = \vec{H_1} + \vec{H_2} = \frac{I}{2\pi d}\vec{Y} + \frac{I}{2\pi d}\vec{Y} = \frac{I}{\pi d}\vec{Y}$$

SOL 1.2.95 Option ( ) is correct.

SOL 1.2.96 Option (C) is correct.

Given that magnitudes of V_L and V_C are twice of V_R

$$|V_L| = |V_C| = 2V_R \quad \text{(Circuit is at resonance)}$$

Voltage across inductor

$$V_L = i_R \times j\omega L$$

Current i_R at resonance

$$i_R = \frac{5\angle 0^\circ}{R} = \frac{5}{5} = 1\text{ A}$$

so, $|V_L| = \omega L = 2V_R$

$\omega L = 2 \times 5$ $\quad V_R = 5$ V, at resonance

$2 \times \pi \times 50 \times L = 10$

$$L = \frac{10}{314} = 31.8\text{ mH}$$

SOL 1.2.97 Option (C) is correct.

Applying nodal analysis in the circuit

At node P

$$2 + \frac{V_P - 10}{2} + \frac{V_P}{8} = 0$$

$$16 + 4V_P - 40 + V_P = 0$$

$$5V_P - 24 = 0$$

$$V_P = \frac{24}{5}\text{ Volt}$$

At node Q

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$$2 = \frac{V_Q - 10}{4} + \frac{V_Q - 0}{6}$$

$$24 = 3V_Q - 30 + 2V_Q$$

$$5V_Q - 54 = 0$$

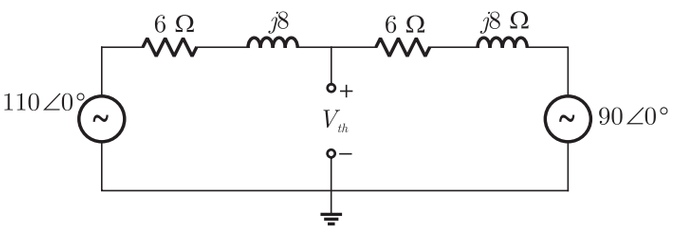
$$V_Q = \frac{54}{5} \text{ V}$$

Potential difference between P-Q

$$V_{PQ} = V_P - V_Q = \frac{24}{5} - \frac{54}{5} = -6 \text{ V}$$

SOL 1.2.98 Option (D) is correct.

First obtain equivalent Thevenin circuit across load R_L



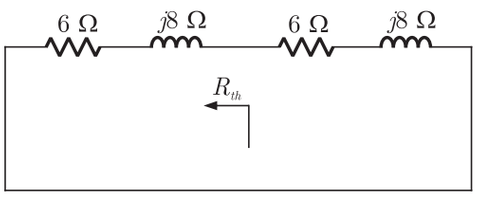
Thevenin voltage

$$\frac{V_{th} - 110\angle 0^\circ}{6 + 8j} + \frac{V_{th} - 90\angle 0^\circ}{6 + 8j} = 0$$

$$2V_{th} - 200\angle 0^\circ = 0$$

$$V_{th} = 100\angle 0^\circ \text{ V}$$

Thevenin impedance

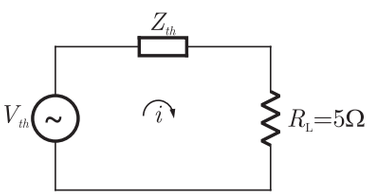


$$Z_{th} = (6 + 8j)\,\Omega \,||\, (6 + 8j)\,\Omega$$

$$= (3 + 4j)\,\Omega$$

For maximum power transfer

$$R_L = |Z_{th}| = \sqrt{3^2 + 4^2} = 5\,\Omega$$



Power in load

$$P = i_{eff}^2 R_L$$

$$P = \left| \frac{100}{3 + 4j + 5} \right|^2 \times 5 = \frac{(100)^2}{80} \times 5 = 625 \text{ Watt}$$

SOL 1.2.99 Option (D) is correct.

By applying mesh analysis in the circuit

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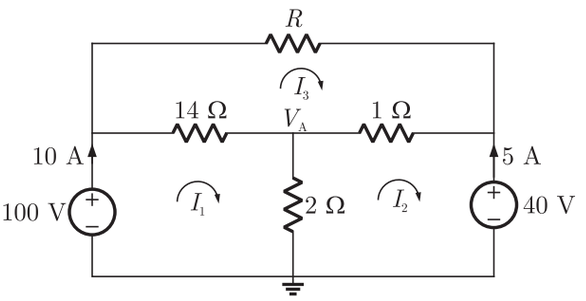


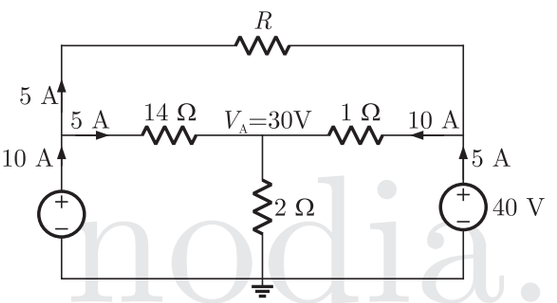
$I_1 = 10$ A, $\quad I_2 = -5$ A

Current in 2 Ω resistor

$$I_{2\Omega} = I_1 - (-I_2) = 10 - (-5) = 15 \text{ A}$$

So, voltage $\quad V_A = 15 \times 2 = 30$ Volt

Now we can easily find out current in all branches as following



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Current in resistor R is 5 A

$$5 = \frac{100 - 40}{R}$$

$$R = \frac{60}{5} = 12\,\Omega$$

SOL 1.2.100 Option (B) is correct.

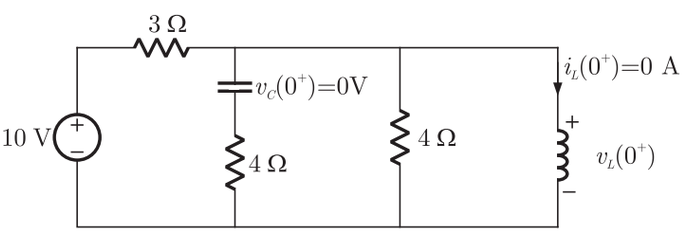
Before $t = 0$, the switch was opened so current in inductor and voltage across capacitor for $t < 0$ is zero

$v_c(0^-) = 0, \quad i_L(0^-) = 0$

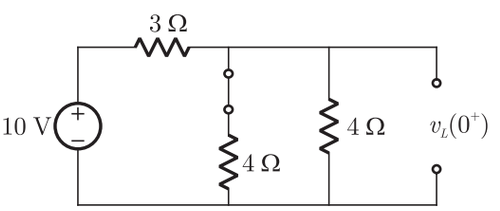
at $t = 0$, when the switch is closed, inductor current and capacitor voltage does not change simultaneously so

$v_c(0^+) = v_c(0^-) = 0, \quad i_L(0^+) = i_L(0^-) = 0$

At $t = 0^+$ the circuit is



Simplified circuit



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Voltage across inductor (at $t = 0^+$)

$$v_L(0^+) = \frac{10}{3+2} \times 2 = 4 \text{ Volt}$$

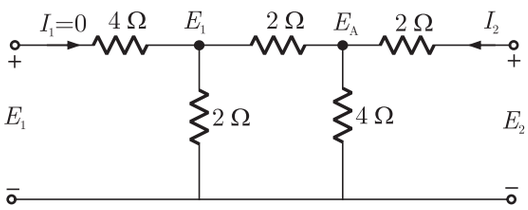
SOL 1.2.101 Option (D) is correct.

Given that $E_1 = h_{11}I_1 + h_{12}E_2$

and $I_2 = h_{21}I_1 + h_{22}E_2$

Parameter h_{12} is given as

$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1 = 0 \text{(open circuit)}}$$



At node A

$$\frac{E_A - E_1}{2} + \frac{E_A - E_2}{2} + \frac{E_A}{4} = 0$$

$$5E_A = 2E_1 + 2E_2 \quad \ldots(1)$$

Similarly

$$\frac{E_1 - E_A}{2} + \frac{E_1}{2} = 0$$

$$2E_1 = E_A \quad \ldots(2)$$

From (1) and (2)

$$5(2E_1) = 2E_1 + 2E_2 4$$

$$8E_1 = 2E_2$$

$$h_{12} = \frac{E_1}{E_2} = \frac{1}{4}$$

SOL 1.2.102 Option (B) is correct.

$$V_{PQ} = V_P - V_Q = \frac{KQ}{\text{OP}} - \frac{KQ}{\text{OQ}}$$

$$= \frac{9 \times 10^9 \times 1 \times 10^{-9}}{40 \times 10^{-3}} - \frac{9 \times 10^9 \times 1 \times 10^{-9}}{20 \times 10^{-3}}$$

$$= 9 \times 10^3 \left[\frac{1}{40} - \frac{1}{20}\right] = -225 \text{ Volt}$$

SOL 1.2.103 Option (D) is correct.

Energy stored in Capacitor is

$$E = \frac{1}{2}CV^2$$

$$C = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 100 \times 10^{-6}}{0.1 \times 10^{-3}} = 8.85 \times 10^{-12} \text{ F}$$

$$E = \frac{1}{2} \times 8.85 \times 10^{-12} \times (100)^2 = 44.3 \text{ nJ}$$

SOL 1.2.104 Option (B) is correct.

The figure is as shown below

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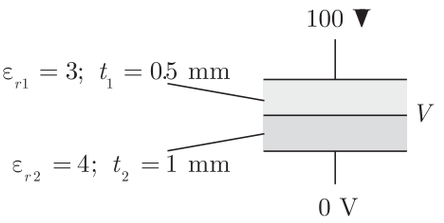

The Capacitor shown in Figure is made up of two capacitor C_1 and C_2 connected in series.

$$C_1 = \frac{\varepsilon_0 \varepsilon_{r1} A}{t_1}, C_2 = \frac{\varepsilon_0 \varepsilon_{r2} A}{t_2}$$

Since C_1 and C_2 are in series charge on both capacitor is same.

$$Q_1 = Q_2$$

$$C_1(100 - V) = C_2 V \text{ (Let V is the voltage of foil)}$$

$$\frac{\varepsilon_0 \varepsilon_{r1} A}{t_1}(100 - V) = \frac{\varepsilon_0 \varepsilon_{r2} A}{t_2} V$$

$$\frac{3}{0.5}(100 - V) = \frac{4}{1} V$$

$$300 - 3V = 2V$$

$$300 = 5V \Rightarrow V = 60 \text{ Volt}$$

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SOL 1.2.105 Option (D) is correct.

Voltage across capacitor is given by

$$v_c(t) = \frac{1}{C}\int_{-\infty}^{\infty} i(t)\,dt = \frac{1}{C}\int_{-\infty}^{\infty} 5\delta(t)\,dt = \frac{5}{C} \times u(t)$$

SOL 1.2.106 Option (C) is correct.

No. of links is given by

$$L = N - B + 1$$

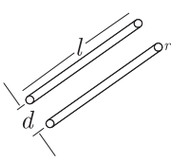
SOL 1.2.107 Option (A) is correct.

Divergence theorem states that the total outward flux of a vector field F through a closed surface is same as volume integral of the divergence of F

$$\oint_S \vec{F} \cdot \vec{ds} = \int_V (\vec{\nabla} \cdot \vec{F})\,dv$$

SOL 1.2.108 Option (C) is correct.

The figure as shown below



Inductance of parallel wire combination is given as

$$L = \frac{\mu_0 l}{\pi} \ln\left(\frac{d}{r}\right)$$

Where $l \rightarrow$ Length of wires

$d \rightarrow$ Distance between wires

$r \rightarrow$ Radius

$L \propto \ln d$

So when d is double, inductance increase but does not double.

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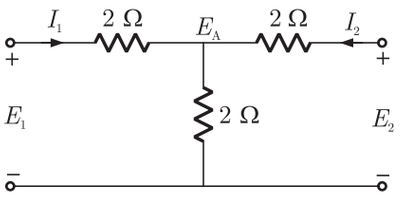
SOL 1.2.109 Option (B) is correct.
Since distance from ground to lower surface is less than from ground to upper surface so electric stress is maximum at lower surface.

SOL 1.2.110 Option (B) is correct.
Writing node equation for the circuit



$$I_1 = \frac{E_1 - E_A}{2}$$

and $$I_2 = \frac{E_2 - E_A}{2}$$

At node A

$$\frac{E_A - E_1}{2} + \frac{E_A}{2} + \frac{E_A - E_2}{2} = 0$$

$$3E_A = E_1 + E_2 \qquad ...(1)$$

From eqn(1)

$$I_1 = \frac{1}{2}E_1 - \frac{1}{2}\frac{(E_1 + E_2)}{3}$$

$$I_1 = \frac{1}{3}E_1 - \frac{1}{6}E_2 \qquad ...(2)$$

Similarly $$I_2 = \frac{1}{2}E_2 - \frac{1}{2}\frac{(E_1 + E_2)}{3}$$

$$I_2 = -\frac{1}{6}E_1 + \frac{1}{3}E_2 \qquad ...(3)$$

From (2) and (3) admittance parameters are

$$[Y_{11} \quad Y_{12} \quad Y_{21} \quad Y_{22}] = [1/3 \quad -1/6 \quad -1/6 \quad 1/3]$$

SOL 1.2.111 Option (A) is correct.
Admittance of the given circuit

$$Y(\omega) = j\omega C + \frac{1}{Z_L}$$

$$Z_L = 30\angle 40^\circ = 23.1 + j19.2\,\Omega$$

So, $$Y(\omega) = j2\pi \times 50 \times C + \frac{1}{23.1 + j19.2} \times \frac{23.1 - j19.2}{23.1 - j19.2}$$

$$= j(100\pi)C + \frac{23.1 - j19.2}{902.25}$$

$$= \frac{23.1}{902.25} + j\left[(100\pi)C - \frac{19.2}{902.25}\right]$$

For unity power factor

$$I_m[Y(\omega)] = 0$$

$$100 \times 3.14 \times C = \frac{19.2}{902.25}$$

$$C \simeq 68.1\,\mu\text{F}$$

SOL 1.2.112 Option (B) is correct.
In series RLC circuit lower half power frequency is given by following relations

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$$\omega_1 L - \frac{1}{\omega_1 C} = -R$$

$$(2\pi \times f_1 \times 100 \times 10^{-6}) - \frac{1}{2\pi \times f_1 (1 \times 10^{-6})} = -50$$

$$f_1 = 3.055 \text{ kHz}$$

SOL 1.2.113 Option (C) is correct.

Since initial charge across capacitor is zero, voltage across capacitor at any time t is given as

$$v_c(t) = 10(1 - e^{-\frac{t}{\tau}})$$

Time constant $\tau = R_{eq} C$

$$= (10\,\text{k}\Omega \,||\, 1\,\text{k}\Omega) \times C$$

$$= \left(\frac{10}{11}\right)\text{k}\Omega \times 11\,\text{nF} = 10 \times 10^{-6} \text{ sec} = 10\,\mu\text{sec}$$

So, $v_c(t) = 10(1 - e^{-\frac{t}{10\,\mu\text{sec}}})$

Pulse duration is $10\,\mu$sec, so voltage across capacitor will be maximum at $t = 10\,\mu$ sec

$$v_c(t = 10\,\mu\text{sec}) = 10(1 - e^{-\frac{10\,\mu\text{sec}}{10\,\mu\text{sec}}}) = 10(1 - e^{-1}) = 6.32 \text{ Volt}$$

SOL 1.2.114 Option (C) is correct.

Since voltage and current are in phase so equivalent inductance is

$$L_{eq} = 12\,\text{H}$$

$$L_1 + L_2 \pm 2M = 12 \qquad M \rightarrow \text{Mutual Inductance}$$

$$8 + 8 \pm 2M = 12$$

$$16 - 2M = 12 \text{ (Dot is at position } Q)$$

$$M = 2 \text{ H}$$

Coupling Coefficient

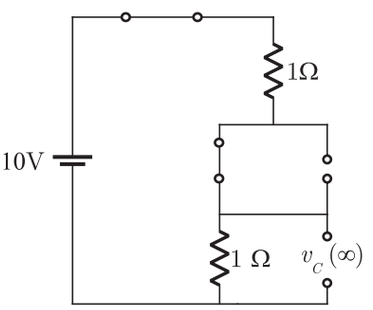
$$K = \frac{2}{\sqrt{8 \times 8}} = 0.25$$

SOL 1.2.115 Option ( ) is correct.

SOL 1.2.116 Option (C) is correct.

In steady state there is no voltage drop across inductor (i.e. it is short circuit) and no current flows through capacitors (i.e. it is open circuit)

The equivalent circuit is



So, $v_c(\infty) = \frac{10}{1+1} \times 1 = 5$ Volt

SOL 1.2.117 Option (C) is correct.

When the switch was closed before $t = 0$, the circuit is

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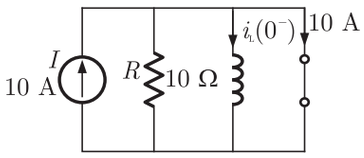
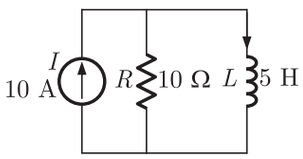


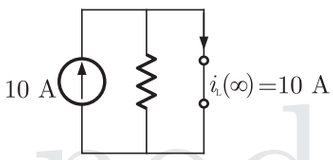
Current in the inductor

$$i_L(0^-) = 0 \text{ A}$$

When the switch was opened at $t = 0$, equivalent circuit is



In steady state, inductor behaves as short circuit and 10 A current flows through it



$$i_L(\infty) = 10 \text{ A}$$

Inductor current at any time t is given by

$$i_L(t) = i_L(\infty) + [i_L(0) - i_L(\infty)]e^{-\frac{R}{L}t}$$
$$= 10 + (0 - 10)e^{-\frac{5}{10}t} = 10(1 - e^{-2t}) \text{ A}$$

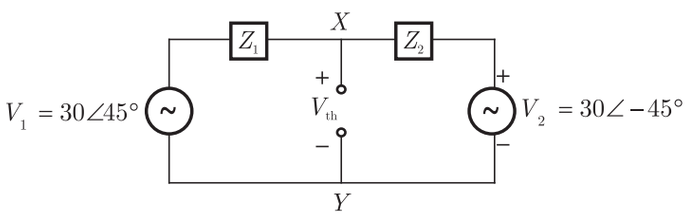
SOL 1.2.118 Option (B) is correct.

Energy stored in inductor is

$$E = \frac{1}{2}Li^2 = \frac{1}{2} \times 5 \times (10)^2 = 250 \text{ J}$$

SOL 1.2.119 Option (C) is correct.

To obtain Thevenin's equivalent, open the terminals X and Y as shown below,



By writing node equation at X

$$\frac{V_{th} - V_1}{Z_1} + \frac{V_{th} - V_2}{Z_2} = 0$$

$$V_1 = 30\angle 45° = \frac{30}{\sqrt{2}}(1 + j)$$

$$V_2 = 30\angle -45° = \frac{30}{\sqrt{2}}(1 - j)$$

So,

$$\frac{V_{th} - \frac{30}{\sqrt{2}}(1 + j)}{1 - j} + \frac{V_{th} - \frac{30}{\sqrt{2}}(1 - j)}{1 + j} = 0$$

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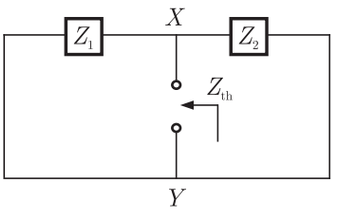
$$2V_{th} - \frac{30}{\sqrt{2}}(1+j)^2 - \frac{30}{\sqrt{2}}(1-j)^2 = 0$$

$$V_{th} = 0 \text{ Volt}$$

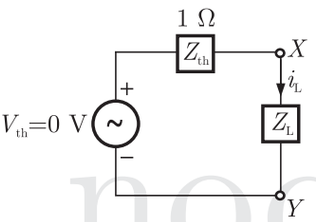
Thevenin's impedance



$$Z_{th} = Z_1 \,||\, Z_2 = (1-j) \,||\, (1+j) = \frac{(1-j)(1+j)}{(1-j)+(1+j)} = 1\,\Omega$$

SOL 1.2.120 Option (A) is correct.

Drawing Thevenin equivalent circuit across load :



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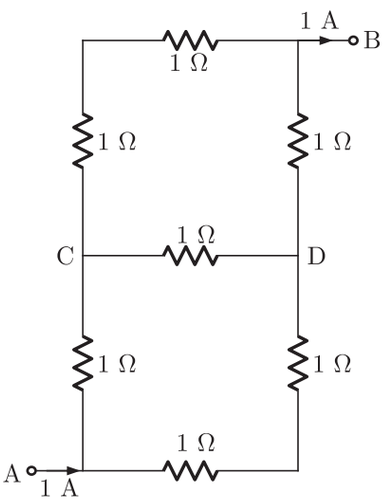
So, current $i_L = 0$ A

SOL 1.2.121 Option (A) is correct.

In the circuit we can observe that there are two wheatstone bridge connected in parallel. Since all resistor values are same, therefore both the bridge are balanced and no current flows through diagonal arm. So the equivalent circuit is



We can draw the circuit as

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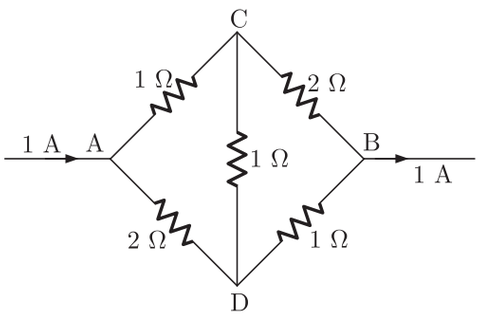
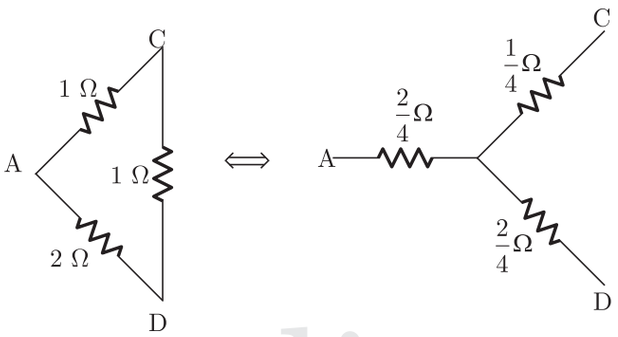
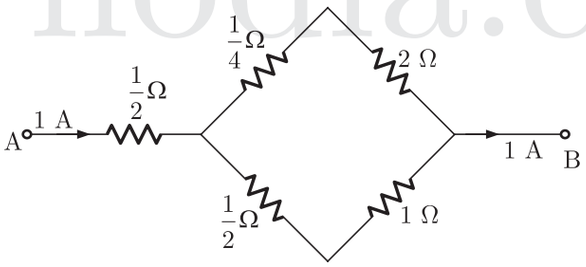
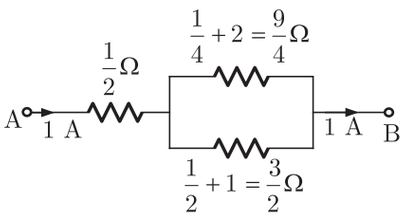


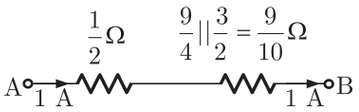
From $\Delta - Y$ conversion

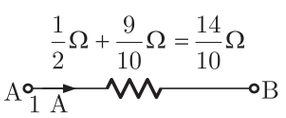


Now the circuit is









$$V_{AB} = 1 \times \frac{14}{10} = 1.4 \text{ Volt}$$

SOL 1.2.122 Option (C) is correct.

In a series RLC circuit, at resonance, current is given as

$$i = \frac{V_s + 0c}{R}, \quad V_S \text{ " source voltage}$$

So, voltage across capacitor at resonance

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$$V_c = \frac{1}{j\omega C} \# \frac{V_s \angle 0^\circ}{R}$$

$$V_c = \frac{V_s}{\omega CR} \angle -90^\circ$$

Voltage across capacitor can be greater than input voltage depending upon values of ω, C and R but it is 90° out of phase with the input

SOL 1.2.123 Option (D) is correct.

Let resistance of 40 W and 60 W lamps are R_1 and R_2 respectively

$$P \propto \frac{1}{R^2}$$

$$\frac{P_1}{P_2} = \frac{R_2}{R_1}$$

$$\frac{R_2}{R_1} = \frac{40}{60}$$

$$R_2 < R_1$$

40 W bulb has high resistance than 60 W bulb, when connected in series power is

$$P_1 = I^2 R_1$$

$$P_2 = I^2 R_2$$

$R_1 > R_2$, So $P_1 > P_2$

Therefore, 40 W bulb glows brighter

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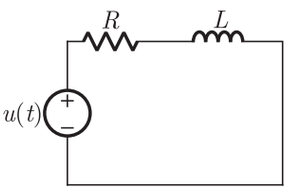
SOL 1.2.124 Option (B) is correct.

Series RL circuit with unit step input is shown in following figure



$$u(t) = \begin{cases} 1, & t > 0 \\ 0, & \text{otherwise} \end{cases}$$

Initially inductor current is zero

$$i(0^+) = 0$$

When unit step is applied, inductor current does not change simultaneously and the source voltage would appear across inductor only so voltage across resistor at $t = 0^+$

$$v_R(0^+) = 0$$

SOL 1.2.125 Option (D) is correct.

For two coupled inductors

$$M = K\sqrt{L_1 L_2}$$

Where K " coupling coefficient

$0 < K \# 1$

So, $$K = \frac{M}{\sqrt{L_1 L_2}} \# 1$$

$$M \# \sqrt{L_1 L_2}$$

SOL 1.2.126 Option (C) is correct.

Since the network contains passive elements only, output can never offer greater

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power compared to input

SOL 1.2.127 Option (B) is correct.

Given that

When terminal C is open

$$R_{AB} = R_A + R_B = 6\,\Omega \qquad ...(1)$$

When terminal A is open

$$R_{BC} = R_B + R_C = 11\,\Omega \qquad ...(2)$$

When terminal B is open

$$R_{AC} = R_A + R_C = 9\,\Omega \qquad (3)$$

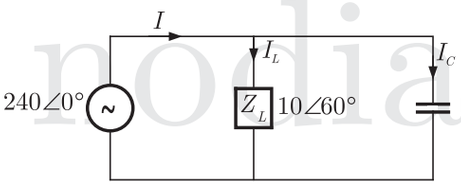
From (1), (2) and (3)

$R_A = 2\,\Omega,\ R_B = 4\,\Omega,\ R_C = 7\,\Omega$

SOL 1.2.128 Option ( ) is correct.

A graph is connected if there exist at least one path between any two vertices (nodes) of the network. So it should have at least N or more branches for one or more closed paths to exist.

SOL 1.2.129 Option (B) is correct.



Current $$I_L = \frac{240\angle 0^\circ}{10\angle 60^\circ} = 24\angle -60^\circ = \frac{24(1-\sqrt{3}j)}{2}\ \text{A}$$

$$= 12 - j20.784\ \text{A}$$

$$I_c = \frac{P}{V} = \frac{j1250}{240\angle 0^\circ} = j5.20\angle 0^\circ\ \text{A}$$

Current $$I = I_C + I_L = 12 - j20.784 + j5.20 = 12 - j15.58$$

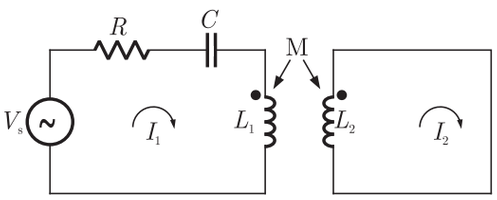
Power supplied by load

$$P = VI = 240(12 - j15.58) = 2880 - 3739j$$

Real power $P_R = 2880$ W

SOL 1.2.130 Option (A) is correct.

Let current in primary and secondary loop is I_1 and I_2 respectively, then by writing KVL equation (considering mutual inductance),



In primary loop

$$V_S - I_1R - I_1\left(\frac{1}{j\omega C}\right) - I_1 j\omega L_1 - I_2 j\omega M = 0$$

$$V_S = I_1\left[R + \frac{1}{j\omega C} + j\omega L_1\right] + j\omega M I_2 \qquad ...(1)$$

In secondary loop

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$$0 - I_2 j\omega L_2 - I_1 j\omega M = 0$$
$$I_2 L_2 + I_1 M = 0$$
$$I_2 = -\frac{M}{L_2} I_1$$

Put I_2 into equation (1)

$$V_s = I_1\left[R + \frac{1}{j\omega C} + j\omega L_1\right] + j\omega M\left(-\frac{M}{L_2}\right)I_1 = 0$$
$$V_s = I_1\left[R + \frac{1}{j\omega C} + j\omega L_1 - \frac{j\omega M^2}{L_2}\right]$$
$$V_s = I_1\left[R + j\left(\omega L_1 - \frac{\omega M^2}{L_2} - \frac{1}{\omega C}\right)\right]$$

For resonance imaginary part must be zero, so

$$\omega L_1 - \frac{\omega M^2}{L_2} - \frac{1}{\omega C} = 0$$
$$\omega^2\left(L_1 - \frac{M^2}{L_2}\right) - \frac{1}{C} = 0$$
$$\omega^2\left(\frac{L_1 L_2 - M^2}{L_2}\right) = \frac{1}{C}$$
$$\omega^2 = \frac{L_2}{C(L_1 L_2 - M^2)}$$

Resonant frequency

$$\omega = \sqrt{\frac{L_2}{C(L_1 L_2 - M^2)}}$$
$$= \sqrt{\frac{10 \times 10^{-3}}{3 \times 10^{-6}[40 \times 10^{-3} \times 10 \times 10^{-3} - (10 \times 10^{-3})^2]}}$$
$$= \frac{1}{3} \times 10^5 \text{ rad/sec}$$

SOL 1.2.131 Option (C) is correct.

Quality factor is given as

$$Q = \frac{\omega L_{eq}}{R} + \frac{1}{\omega C R}$$

Where, $\omega = \frac{1}{3} \times 10^5$ rad/sec

$$L_{eq} = L_1 - \frac{M^2}{L_2} = 40 \times 10^{-3} - \frac{(10 \times 10^{-3})^2}{10 \times 10^{-3}}$$
$$= 3 \times 10^{-2} \text{ H}$$

So, $$Q = \frac{10^5}{3} \times \frac{3 \times 10^{-2}}{10} + \frac{3}{10^5 \times 3 \times 10^{-6} \times 10}$$
$$= 100 + 1 = 101$$

SOL 1.2.132 Option (C) is correct.

Voltage and electric field are related as

$$E = -\nabla V \qquad \text{(Gradient of } V\text{)}$$
$$= -\left[\frac{\partial V_x}{\partial x}\hat{i} + \frac{\partial V_y}{\partial y}\hat{j} + \frac{\partial V_z}{\partial z}\hat{k}\right]$$
$$= -\left[\frac{\partial (50x^2)}{\partial x}\hat{i} + \frac{\partial (50y^2)}{\partial y}\hat{j} + \frac{\partial (50z^2)}{\partial z}\hat{k}\right]$$
$$= -\left[100x\,\hat{i} + 100y\,\hat{j} + 100z\,\hat{k}\right]$$
$$E(1,-1,1) = -\left[100\hat{i} - 100\hat{j} + 100\hat{k}\right] = -100\hat{i} + 100\hat{j} - 100\hat{k}$$

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$$E(1,-1,1) = 100\sqrt{3}\left[\frac{-\hat{i}+\hat{j}-\hat{k}}{\sqrt{3}}\right]$$

SOL 1.2.133 Option (C) is correct.

Power loss in watt is given as

$$P_h = W_h V f$$

Where $W_h \rightarrow$ Energy Density Loss

$V \rightarrow$ Volume of Material

Here $W_h V =$ Area of hysteresis loop

$= 5 \text{ cm}^2$

So, $P_h = 5 \text{ cm}^2 \times 50$

$= 5 \times 2 \times 50 \times 10^{-3} \times 50 = 25 \text{ Watt}$

SOL 1.2.134 Option (C) is correct.

For two parallel wires inductance is

$$L = \frac{\mu_0 l}{\pi}\ln\left(\frac{d}{r}\right)$$

$l \rightarrow$ Length of the wires

$d \rightarrow$ Distance between the wires

$r \rightarrow$ RadiusThus

$$L = \frac{4\pi \times 10^{-7} \times 10 \times 10^{3}}{\pi}\ln\left(\frac{1.5}{0.5 \times 10^{-2}}\right)$$

$$= 4 \times 10^{-3}\ln(300) = 22.81 \text{ mH}$$

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3

SIGNALS & SYSTEMS

YEAR 2013 — ONE MARK

MCQ 1.3.1 A band-limited signal with a maximum frequency of 5 kHz is to be sampled. According to the sampling theorem, the sampling frequency which is not valid is

(A) 5 kHz
(B) 12 kHz
(C) 15 kHz
(D) 20 kHz

MCQ 1.3.2 For a periodic signal $v(t) = 30\sin 100t + 10\cos 300t + 6\sin(500t + \pi/4)$, the fundamental frequency in rad/s

(A) 100
(B) 300
(C) 500
(D) 1500

MCQ 1.3.3 Two systems with impulse responses $h_1(t)$ and $h_2(t)$ are connected in cascade. Then the overall impulse response of the cascaded system is given by

(A) product of $h_1(t)$ and $h_2(t)$
(B) sum of $h_1(t)$ and $h_2(t)$
(C) convolution of $h_1(t)$ and $h_2(t)$
(D) subtraction of $h_2(t)$ from $h_1(t)$

MCQ 1.3.4 Which one of the following statements is NOT TRUE for a continuous time causal and stable LTI system?

(A) All the poles of the system must lie on the left side of the $j\omega$ axis
(B) Zeros of the system can lie anywhere in the s-plane
(C) All the poles must lie within $|s| = 1$
(D) All the roots of the characteristic equation must be located on the left side of the $j\omega$ axis.

MCQ 1.3.5 The impulse response of a system is $h(t) = tu(t)$. For an input $u(t-1)$, the output is

(A) $\frac{t^2}{2}u(t)$
(B) $\frac{t(t-1)}{2}u(t-1)$
(C) $\frac{(t-1)^2}{2}u(t-1)$
(D) $\frac{t^2-1}{2}u(t-1)$

YEAR 2013 — TWO MARKS

MCQ 1.3.6 The impulse response of a continuous time system is given by $h(t) = \delta(t-1) + \delta(t-3)$. The value of the step response at $t = 2$ is

(A) 0
(B) 1
(C) 2
(D) 3

YEAR 2012 ONE MARK

MCQ 1.3.7 If $x[n]=(1/3)^{|n|}-(1/2)^n u[n]$, then the region of convergence (ROC) of its z-transform in the z-plane will be

(A) $\frac{1}{3}<|z|<3$ (B) $\frac{1}{3}<|z|<\frac{1}{2}$

(C) $\frac{1}{2}<|z|<3$ (D) $\frac{1}{3}<|z|$

MCQ 1.3.8 The unilateral Laplace transform of $f(t)$ is $\frac{1}{s^2+s+1}$. The unilateral Laplace transform of $tf(t)$ is

(A) $-\frac{s}{(s^2+s+1)^2}$ (B) $-\frac{2s+1}{(s^2+s+1)^2}$

(C) $\frac{s}{(s^2+s+1)^2}$ (D) $\frac{2s+1}{(s^2+s+1)^2}$

YEAR 2012 TWO MARKS

MCQ 1.3.9 Let $y[n]$ denote the convolution of $h[n]$ and $g[n]$, where $h[n]=(1/2)^n u[n]$ and $g[n]$ is a causal sequence. If $y[0]=1$ and $y[1]=1/2$, then $g[1]$ equals

(A) 0 (B) 1/2

(C) 1 (D) 3/2

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MCQ 1.3.10 The Fourier transform of a signal $h(t)$ is $H(j\omega)=(2\cos\omega)(\sin 2\omega)/\omega$. The value of $h(0)$ is

(A) 1/4 (B) 1/2

(C) 1 (D) 2

MCQ 1.3.11 The input $x(t)$ and output $y(t)$ of a system are related as $y(t)=\int_{-\infty}^{t} x(\tau)\cos(3\tau)\,d\tau$. The system is

(A) time-invariant and stable

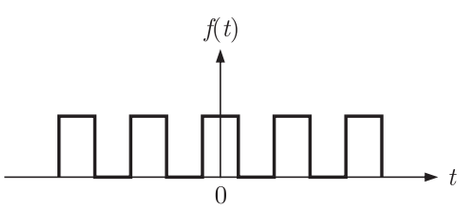
(B) stable and not time-invariant

(C) time-invariant and not stable

(D) not time-invariant and not stable

YEAR 2011 ONE MARK

MCQ 1.3.12 The Fourier series expansion $f(t)=a_0+\sum_{n=1}^{\infty} a_n\cos n\omega t+b_n\sin n\omega t$ of the periodic signal shown below will contain the following nonzero terms



(A) a_0 and $b_n, n=1,3,5,\ldots\infty$ (B) a_0 and $a_n, n=1,2,3,\ldots\infty$

(C) $a_0 a_n$ and $b_n, n=1,2,3,\ldots\infty$ (D) a_0 and $a_n\ n=1,3,5,\ldots\infty$

MCQ 1.3.13 Given two continuous time signals $x(t)=e^{-t}$ and $y(t)=e^{-2t}$ which exist for $t>0$, the convolution $z(t)=x(t)^* y(t)$ is

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(A) $e^{-t}-e^{-2t}$ (B) e^{-3t}

(C) e^{+t} (D) $e^{-t}+e^{-2t}$

YEAR 2011 TWO MARKS

MCQ 1.3.14 Let the Laplace transform of a function $f(t)$ which exists for $t>0$ be $F_1(s)$ and the Laplace transform of its delayed version $f(t-\tau)$ be $F_2(s)$. Let $F_1{}^*(s)$ be the complex conjugate of $F_1(s)$ with the Laplace variable set $s=\sigma+j\omega$. If $G(s)=\dfrac{F_2(s)F_1{}^*(s)}{\left|F_1(s)\right|^2}$, then the inverse Laplace transform of $G(s)$ is an ideal

(A) impulse $\delta(t)$ (B) delayed impulse $\delta(t-\tau)$

(C) step function $u(t)$ (D) delayed step function $u(t-\tau)$

MCQ 1.3.15 The response $h(t)$ of a linear time invariant system to an impulse $\delta(t)$, under initially relaxed condition is $h(t)=e^{-t}+e^{-2t}$. The response of this system for a unit step input $u(t)$ is

(A) $u(t)+e^{-t}+e^{-2t}$ (B) $(e^{-t}+e^{-2t})u(t)$

(C) $(1.5-e^{-t}-0.5e^{-2t})u(t)$ (D) $e^{-t}\delta(t)+e^{-2t}u(t)$

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YEAR 2010 ONE MARK

MCQ 1.3.16 For the system $2/(s+1)$, the approximate time taken for a step response to reach 98% of the final value is

(A) 1 s (B) 2 s

(C) 4 s (D) 8 s

MCQ 1.3.17 The period of the signal $x(t)=8\sin\left(0.8\pi t+\dfrac{\pi}{4}\right)$ is

(A) 0.4π s (B) 0.8π s

(C) 1.25 s (D) 2.5 s

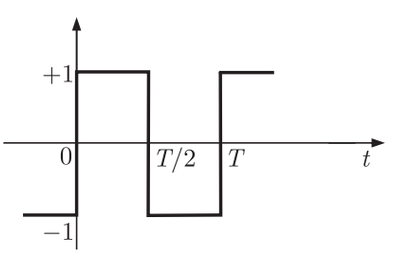
MCQ 1.3.18 The system represented by the input-output relationship

$$y(t)=\int_{-\infty}^{5t}x(\tau)\,d\tau,\ t>0$$

(A) Linear and causal (B) Linear but not causal

(C) Causal but not linear (D) Neither liner nor causal

MCQ 1.3.19 The second harmonic component of the periodic waveform given in the figure has an amplitude of



(A) 0 (B) 1

(C) $2/\pi$ (D) $\sqrt{5}$

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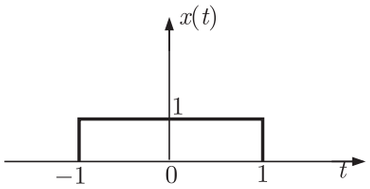
YEAR 2010 TWO MARKS

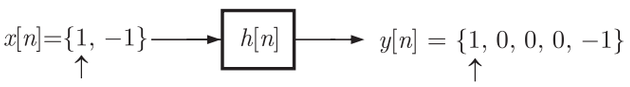
MCQ 1.3.20 $x(t)$ is a positive rectangular pulse from $t=-1$ to $t=+1$ with unit height as shown in the figure. The value of $\int_{-3}^{3}|X(\omega)|^2 d\omega$ "where $X(\omega)$ is the Fourier transform of $x(t)$} is.



(A) 2 (B) 2π

(C) 4 (D) 4π

MCQ 1.3.21 Given the finite length input $x[n]$ and the corresponding finite length output $y[n]$ of an LTI system as shown below, the impulse response $h[n]$ of the system is



(A) $h[n]=\underset{\uparrow}{\{1,0,0,1\}}$ (B) $h[n]=\underset{\uparrow}{\{1,0,1\}}$

(C) $h[n]=\underset{\uparrow}{\{1,1,1,1\}}$ (D) $h[n]=\underset{\uparrow}{\{1,1,1\}}$

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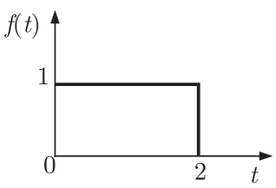
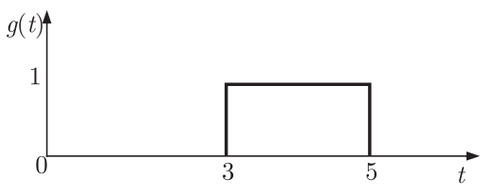
Common Data Questions Q.22-23.

Given $f(t)$ and $g(t)$ as show below





MCQ 1.3.22 $g(t)$ can be expressed as

(A) $g(t)=f(2t-3)$ (B) $g(t)=f\left(\frac{t}{2}-3\right)$

(C) $g(t)=f\left(2t-\frac{3}{2}\right)$ (D) $g(t)=f\left(\frac{t}{2}-\frac{3}{2}\right)$

MCQ 1.3.23 The Laplace transform of $g(t)$ is

(A) $\frac{1}{s}(e^{3s}-e^{5s})$ (B) $\frac{1}{s}(e^{-5s}-e^{-3s})$

(C) $\frac{e^{-3s}}{s}(1-e^{-2s})$ (D) $\frac{1}{s}(e^{5s}-e^{3s})$

YEAR 2009 ONE MARK

MCQ 1.3.24 A Linear Time Invariant system with an impulse response $h(t)$ produces output $y(t)$ when input $x(t)$ is applied. When the input $x(t-\tau)$ is applied to a system with impulse response $h(t-\tau)$, the output will be

(A) $y(\tau)$ (B) $y(2(t-\tau))$

(C) $y(t-\tau)$ (D) $y(t-2\tau)$

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YEAR 2009 TWO MARKS

MCQ 1.3.25 A cascade of three Linear Time Invariant systems is causal and unstable. From this, we conclude that

(A) each system in the cascade is individually causal and unstable

(B) at least on system is unstable and at least one system is causal

(C) at least one system is causal and all systems are unstable

(D) the majority are unstable and the majority are causal

MCQ 1.3.26 The Fourier Series coefficients of a periodic signal $x(t)$ expressed as $x(t) = \sum_{k=-3}^{3} a_k e^{j2\pi kt/T}$ are given by $a_{-2} = 2 - j1$, $a_{-1} = 0.5 + j0.2$, $a_0 = j2$, $a_1 = 0.5 - j0.2$, $a_2 = 2 + j1$ and $a_k = 0$ for $|k| > 2$

Which of the following is true ?

(A) $x(t)$ has finite energy because only finitely many coefficients are non-zero

(B) $x(t)$ has zero average value because it is periodic

(C) The imaginary part of $x(t)$ is constant

(D) The real part of $x(t)$ is even

MCQ 1.3.27 The z-transform of a signal $x[n]$ is given by $4z^{-3} + 3z^{-1} + 2 - 6z^2 + 2z^3$

It is applied to a system, with a transfer function $H(z) = 3z^{-1} - 2$

Let the output be $y[n]$. Which of the following is true ?

(A) $y[n]$ is non causal with finite support

(B) $y[n]$ is causal with infinite support

(C) $y[n] = 0; |n| > 3$

(D) $\text{Re}[Y(z)]_{z=e^{j\theta}} = -\text{Re}[Y(z)]_{z=e^{-j\theta}}$

$\text{Im}[Y(z)]_{z=e^{j\theta}} = \text{Im}[Y(z)]_{z=e^{-j\theta}}; \quad -\pi \# \theta < \pi$

YEAR 2008 ONE MARK

MCQ 1.3.28 The impulse response of a causal linear time-invariant system is given as $h(t)$. Now consider the following two statements :

Statement (I): Principle of superposition holds

Statement (II): $h(t) = 0$ for $t < 0$

Which one of the following statements is correct ?

(A) Statements (I) is correct and statement (II) is wrong

(B) Statements (II) is correct and statement (I) is wrong

(C) Both Statement (I) and Statement (II) are wrong

(D) Both Statement (I) and Statement (II) are correct

MCQ 1.3.29 A signal $e^{-\alpha t}\sin(\omega t)$ is the input to a real Linear Time Invariant system. Given K and ϕ are constants, the output of the system will be of the form $Ke^{-\beta t}\sin(\nu t + \phi)$ where

(A) β need not be equal to α but ν equal to ω

(B) ν need not be equal to ω but β equal to α

(C) β equal to α and ν equal to ω

(D) β need not be equal to α and ν need not be equal to ω

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YEAR 2008 TWO MARKS

MCQ 1.3.30 A system with $x(t)$ and output $y(t)$ is defined by the input-output relation :

$$y(t) = \int_{-3}^{-2t} x(t)\,d\tau$$

The system will be

(A) Casual, time-invariant and unstable

(B) Casual, time-invariant and stable

(C) non-casual, time-invariant and unstable

(D) non-casual, time-variant and unstable

MCQ 1.3.31 A signal $x(t) = \text{sinc}(\alpha t)$ where α is a real constant $\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$ is the input to a Linear Time Invariant system whose impulse response $h(t) = \text{sinc}(\beta t)$, where β is a real constant. If min (α, β) denotes the minimum of α and β and similarly, max (α,β) denotes the maximum of α and β, and K is a constant, which one of the following statements is true about the output of the system ?

(A) It will be of the form $K\text{sinc}(\gamma t)$ where $\gamma = \min(\alpha, \beta)$

(B) It will be of the form $K\text{sinc}(\gamma t)$ where $\gamma = \max(\alpha, \beta)$

(C) It will be of the form $K\text{sinc}(\alpha t)$

(D) It can not be a sinc type of signal

MCQ 1.3.32 Let $x(t)$ be a periodic signal with time period T, Let $y(t) = x(t - t_0) + x(t + t_0)$ for some t_0. The Fourier Series coefficients of $y(t)$ are denoted by b_k. If $b_k = 0$ for all odd k, then t_0 can be equal to

(A) $T/8$ (B) $T/4$

(C) $T/2$ (D) $2T$

MCQ 1.3.33 $H(z)$ is a transfer function of a real system. When a signal $x[n] = (1 + j)^n$ is the input to such a system, the output is zero. Further, the Region of convergence (ROC) of $\left(1 - \frac{1}{2}z^{-1}\right)$ H(z) is the entire Z-plane (except $z = 0$). It can then be inferred that $H(z)$ can have a minimum of

(A) one pole and one zero

(B) one pole and two zeros

(C) two poles and one zero

D) two poles and two zeros

MCQ 1.3.34 Given $X(z) = \frac{z}{(z-a)^2}$ with $|z| > a$, the residue of $X(z)z^{n-1}$ at $z = a$ for $n \geq 0$ will be

(A) a^{n-1} (B) a^n

(C) na^n (D) na^{n-1}

MCQ 1.3.35 Let $x(t) = \text{rect}\left(t - \frac{1}{2}\right)$ (where $rect(x) = 1$ for $-\frac{1}{2} \leq x \leq \frac{1}{2}$ and zero otherwise.

If $\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$, then the FTof $x(t) + x(-t)$ will be given by

(A) $\text{sinc}\left(\frac{\omega}{2\pi}\right)$ (B) $2\text{sinc}\left(\frac{\omega}{2\pi}\right)$

(C) $2\text{sinc}\left(\frac{\omega}{2\pi}\right)\cos\left(\frac{\omega}{2}\right)$ (D) $\text{sinc}\left(\frac{\omega}{2\pi}\right)\sin\left(\frac{\omega}{2}\right)$

MCQ 1.3.36 Given a sequence $x[n]$, to generate the sequence $y[n] = x[3 - 4n]$, which one of the following procedures would be correct ?

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(A) First delay $x(n)$ by 3 samples to generate $z_1[n]$, then pick every 4^{th} sample of $z_1[n]$ to generate $z_2[n]$, and than finally time reverse $z_2[n]$ to obtain $y[n]$.

(B) First advance $x[n]$ by 3 samples to generate $z_1[n]$, then pick every 4^{th} sample of $z_1[n]$ to generate $z_2[n]$, and then finally time reverse $z_2[n]$ to obtain $y[n]$

(C) First pick every fourth sample of $x[n]$ to generate $v_1[n]$, time-reverse $v_1[n]$ to obtain $v_2[n]$, and finally advance $v_2[n]$ by 3 samples to obtain $y[n]$

(D) First pick every fourth sample of $x[n]$ to generate $v_1[n]$, time-reverse $v_1[n]$ to obtain $v_2[n]$, and finally delay $v_2[n]$ by 3 samples to obtain $y[n]$

YEAR 2007 ONE MARK

MCQ 1.3.37 Let a signal $a_1 \sin(\omega_1 t + \phi)$ be applied to a stable linear time variant system. Let the corresponding steady state output be represented as $a_2 F(\omega_2 t + \phi_2)$. Then which of the following statement is true?

(A) F is not necessarily a "Sine" or "Cosine" function but must be periodic with $\omega_1 = \omega_2$.

(B) F must be a "Sine" or "Cosine" function with $a_1 = a_2$

(C) F must be a "Sine" function with $\omega_1 = \omega_2$ and $\phi_1 = \phi_2$

(D) F must be a "Sine" or "Cosine" function with $\omega_1 = \omega_2$

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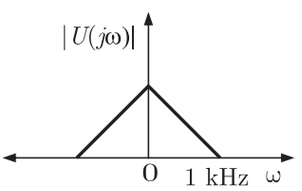
MCQ 1.3.38 The frequency spectrum of a signal is shown in the figure. If this is ideally sampled at intervals of 1 ms, then the frequency spectrum of the sampled signal will be



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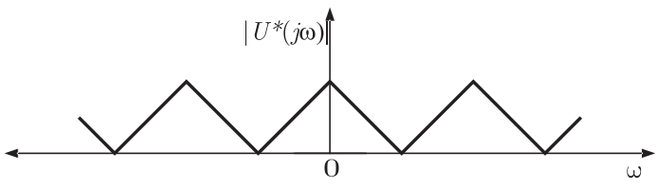
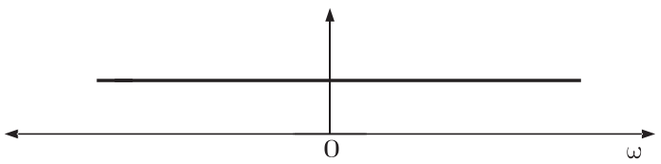
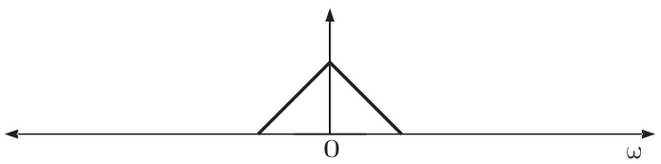
(A)



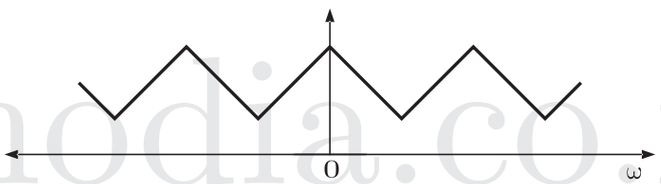
(B)



(C)



(D)



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YEAR 2007 TWO MARKS

MCQ 1.3.39 A signal $x(t)$ is given by

$$x(t) = \begin{cases} 1, -T/4 < t \# 3T/4 \\ -1, 3T/4 < t \# 7T/4 \\ -x(t+T) \end{cases}$$

Which among the following gives the fundamental fourier term of $x(t)$?

(A) $\frac{4}{\pi}\cos\left(\frac{\pi t}{T}\right) - \frac{\pi}{4}$j

(B) $\frac{\pi}{4}\cos\left(\frac{\pi t}{2T}\right) + \frac{\pi}{4}$j

(C) $\frac{4}{\pi}\sin\left(\frac{\pi t}{T}\right) - \frac{\pi}{4}$j

(D) $\frac{\pi}{4}\sin\left(\frac{\pi t}{2T}\right) + \frac{\pi}{4}$j

Statement for Linked Answer Question 41 and 41 :

MCQ 1.3.40 A signal is processed by a causal filter with transfer function $G(s)$
For a distortion free output signal wave form, $G(s)$ must

(A) provides zero phase shift for all frequency

(B) provides constant phase shift for all frequency

(C) provides linear phase shift that is proportional to frequency

(D) provides a phase shift that is inversely proportional to frequency

MCQ 1.3.41 $G(z) = \alpha z^{-1} + \beta z^{-3}$ is a low pass digital filter with a phase characteristics same as that of the above question if

(A) $\alpha = \beta$

(B) $\alpha = -\beta$

(C) $\alpha = \beta^{(1/3)}$

(D) $\alpha = \beta^{(-1/3)}$

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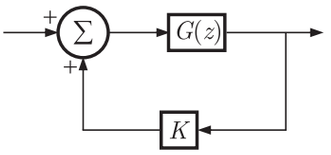
MCQ 1.3.42 Consider the discrete-time system shown in the figure where the impulse response of $G(z)$ is $g(0)=0, g(1)=g(2)=1, g(3)=g(4)=\text{g}=0$



This system is stable for range of values of K

(A) $[-1,\ \frac{1}{2}]$ (B) $[-1,\ 1]$

(C) $[-\frac{1}{2},\ 1]$ (D) $[-\frac{1}{2},\ 2]$

MCQ 1.3.43 If $u(t), r(t)$ denote the unit step and unit ramp functions respectively and $u(t) * r(t)$ their convolution, then the function $u(t+1) * r(t-2)$ is given by

(A) $\frac{1}{2}(t-1)u(t-1)$ (B) $\frac{1}{2}(t-1)u(t-2)$

(C) $\frac{1}{2}(t-1)^2 u(t-1)$ (D) None of the above

MCQ 1.3.44 $X(z)=1-3z^{-1}$, $Y(z)=1+2z^{-2}$ are Z transforms of two signals $x[n], y[n]$ respectively. A linear time invariant system has the impulse response $h[n]$ defined by these two signals as $h[n]=x[n-1]*y[n]$ where * denotes discrete time convolution. Then the output of the system for the input $\delta[n-1]$

(A) has Z-transform $z^{-1}X(z)Y(z)$

(B) equals $\delta[n-2]-3\delta[n-3]+2\delta[n-4]-6\delta[n-5]$

(C) has Z-transform $1-3z^{-1}+2z^{-2}-6z^{-3}$

(D) does not satisfy any of the above three

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MCQ 1.3.45 The following is true

(A) A finite signal is always bounded

(B) A bounded signal always possesses finite energy

(C) A bounded signal is always zero outside the interval $[-t_0, t_0]$ for some t_0

(D) A bounded signal is always finite

MCQ 1.3.46 $x(t)$ is a real valued function of a real variable with period T. Its trigonometric Fourier Series expansion contains no terms of frequency $\omega=2\pi(2k)/T; k=1,2\,\text{g}$ Also, no sine terms are present. Then $x(t)$ satisfies the equation

(A) $x(t)=-x(t-T)$

(B) $x(t)=x(T-t)=-x(-t)$

(C) $x(t)=x(T-t)=-x(t-T/2)$

(D) $x(t)=x(t-T)=x(t-T/2)$

MCQ 1.3.47 A discrete real all pass system has a pole at $z=2+30^{\circ}$: it, therefore

(A) also has a pole at $\frac{1}{2}+30^{\circ}$

(B) has a constant phase response over the z-plane: $\arg|H(z)|=$ constantconstant

(C) is stable only if it is anti-causal

(D) has a constant phase response over the unit circle: $\arg|H(e^{i\Omega})|=$ constant

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MCQ 1.3.48 $x[n]=0;n<-1,n>0,x[-1]=-1,x[0]=2$ is the input and $y[n]=0;n<-1,n>2,y[-1]=-1=y[1],y[0]=3,y[2]=-2$ is the output of a discrete-time LTI system. The system impulse response $h[n]$ will be

(A) $h[n]=0;n<0,n>2,h[0]=1,h[1]=h[2]=-1$

(B) $h[n]=0;n<-1,n>1,h[-1]=1,h[0]=h[1]=2$

(C) $h[n]=0;n<0,n>3,h[0]=-1,h[1]=2,h[2]=1$

(D) $h[n]=0;n<-2,n>1,h[-2]=h[1]=h[-1]=-h[0]=3$

MCQ 1.3.49 The discrete-time signal $x[n] \longleftrightarrow X(z)=\sum_{n=0}^{3}\frac{3^n}{2+n}z^{2n}$, where $\longleftrightarrow$ denotes a transform-pair relationship, is orthogonal to the signal

(A) $y_1[n]$) $Y_1(z)=\sum_{n=0}^{3}\left(\frac{2}{3}\right)^n z^{-n}$

(B) $y_2[n]$) $Y_2(z)=\sum_{n=0}^{3}(5^n-n)z^{-(2n+1)}$

(C) $y_3[n]$) $Y_3(z)=\sum_{n=-3}^{3}2^{-|n|}z^{-n}$

(D) $y_4[n]$) $Y_4(z)=2z^{-4}+3z^{-2}+1$

MCQ 1.3.50 A continuous-time system is described by $y(t)=e^{-|x(t)|}$, where $y(t)$ is the output and $x(t)$ is the input. $y(t)$ is bounded

(A) only when $x(t)$ is bounded

(B) only when $x(t)$ is non-negative

(C) only for $t \# 0$ if $x(t)$ is bounded for $t \$ 0$

(D) even when $x(t)$ is not bounded

MCQ 1.3.51 The running integration, given by $y(t)=\int_{-3}^{t}x(t')dt'$

(A) has no finite singularities in its double sided Laplace Transform $Y(s)$

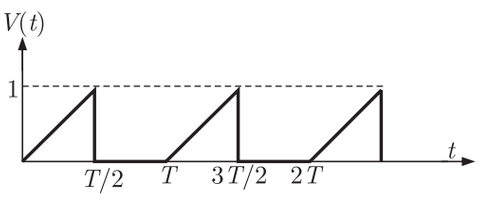
(B) produces a bounded output for every causal bounded input

(C) produces a bounded output for every anticausal bounded input

(D) has no finite zeroes in its double sided Laplace Transform $Y(s)$

YEAR 2005 TWO MARKS

MCQ 1.3.52 For the triangular wave from shown in the figure, the RMS value of the voltage is equal to



(A) $\sqrt{\frac{1}{6}}$ (B) $\sqrt{\frac{1}{3}}$

(C) $\frac{1}{3}$ (D) $\sqrt{\frac{2}{3}}$

MCQ 1.3.53 The Laplace transform of a function $f(t)$ is $F(s)=\frac{5s^2+23s+6}{s(s^2+2s+2)}$ as t " 3, $f(t)$ approaches

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(A) 3 (B) 5

(C) $\frac{17}{2}$ (D) 3

MCQ 1.3.54 The Fourier series for the function $f(x) = \sin^2 x$ is

(A) $\sin x + \sin 2x$

(B) $1 - \cos 2x$

(C) $\sin 2x + \cos 2x$

(D) $0.5 - 0.5\cos 2x$

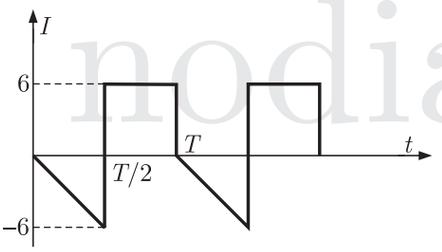
MCQ 1.3.55 If $u(t)$ is the unit step and $\delta(t)$ is the unit impulse function, the inverse z -transform of $F(z) = \frac{1}{z+1}$ for $k > 0$ is

(A) $(-1)^k \delta(k)$ (B) $\delta(k) - (-1)^k$

(C) $(-1)^k u(k)$ (D) $u(k) - (-1)^k$

YEAR 2004 TWO MARKS

MCQ 1.3.56 The rms value of the periodic waveform given in figure is



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(A) $2\sqrt{6}$ A (B) $6\sqrt{2}$ A

(C) $\sqrt{4/3}$ A (D) 1.5 A

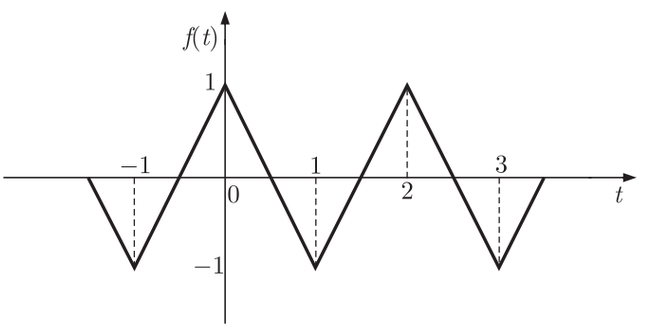
MCQ 1.3.57 The rms value of the resultant current in a wire which carries a dc current of 10 A and a sinusoidal alternating current of peak value 20 is

(A) 14.1 A (B) 17.3 A

(C) 22.4 A (D) 30.0 A

YEAR 2002 ONE MARK

MCQ 1.3.58 Fourier Series for the waveform, $f(t)$ shown in Figure is



(A) $\frac{8}{\pi^2}\left[\sin(\pi t) + \frac{1}{9}\sin(3\pi t) + \frac{1}{25}\sin(5\pi t) + ...\right]$

(B) $\frac{8}{\pi^2}\left[\sin(\pi t) - \frac{1}{9}\cos(3\pi t) + \frac{1}{25}\sin(5\pi t) + ...\right]$

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(C) $\frac{8}{\pi^2}\left\{\cos(\pi t)+\frac{1}{9}\cos(3\pi t)+\frac{1}{25}\cos(5\pi t)+\ldots..\right\}$

(D) $\frac{8}{\pi^2}\left\{\cos(\pi t)-\frac{1}{9}\sin(3\pi t)+\frac{1}{25}\sin(5\pi t)+\ldots....\right\}$

MCQ 1.3.59 Let $s(t)$ be the step response of a linear system with zero initial conditions; then the response of this system to an an input $u(t)$ is

(A) $\int_0^t s(t-\tau)\,u(\tau)\,d\tau$

(B) $\frac{d}{dt}\left[\int_0^t s(t-\tau)\,u(\tau)\,d\tau\right]$

(C) $\int_0^t s(t-\tau)\left[\int_0^t u(\tau_1)\,d\tau_1\right]d\tau$

(D) $\int_0^1 [s(t-\tau)]^2 u(\tau)\,d\tau$

MCQ 1.3.60 Let $Y(s)$ be the Laplace transformation of the function $y(t)$, then the final value of the function is

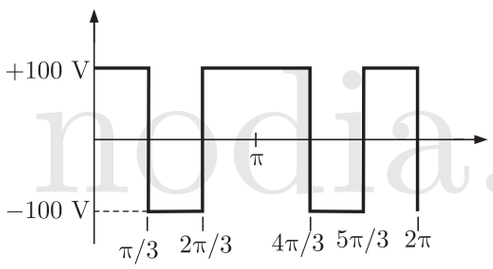
(A) $\lim_{s\to 0} Y(s)$

(B) $\lim_{s\to \infty} Y(s)$

(C) $\lim_{s\to 0} sY(s)$

(D) $\lim_{s\to \infty} sY(s)$

MCQ 1.3.61 What is the rms value of the voltage waveform shown in Figure ?



(A) $(200/\pi)$ V

(B) $(100/\pi)$ V

(C) 200 V

(D) 100 V

YEAR 2001 ONE MARK

MCQ 1.3.62 Given the relationship between the input $u(t)$ and the output $y(t)$ to be

$$y(t)=\int_0^t (2+t-\tau)\,e^{-3(t-\tau)}u(\tau)\,d\tau,$$

The transfer function $Y(s)/U(s)$ is

(A) $\frac{2e^{-2s}}{s+3}$

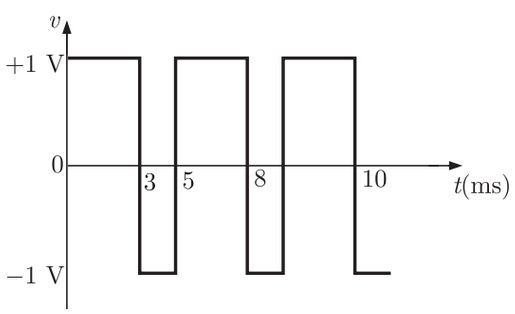
(B) $\frac{s+2}{(s+3)^2}$

(C) $\frac{2s+5}{s+3}$

(D) $\frac{2s+7}{(s+3)^2}$

Common data Questions Q.63-64*

Consider the voltage waveform v as shown in figure



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MCQ 1.3.63 The DC component of v is

(A) 0.4 (B) 0.2

(C) 0.8 (D) 0.1

MCQ 1.3.64 The amplitude of fundamental component of v is

(A) 1.20 V (B) 2.40 V

(C) 2 V (D) 1 V

****

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SOLUTION

SOL 1.3.1 Option (A) is correct.

Given, the maximum frequency of the band-limited signal

$$f_m = 5\,\text{kHz}$$

According to the Nyquist sampling theorem, the sampling frequency must be greater than the Nyquist frequency which is given as

$$f_N = 2f_m = 2 \times 5 = 10\,\text{kHz}$$

So, the sampling frequency f_s must satisfy

$$f_s \geq f_N$$
$$f_s \geq 10\,\text{kHz}$$

only the option (A) does not satisfy the condition therefore, $5\,\text{kHz}$ is not a valid sampling frequency.

SOL 1.3.2 Option (A) is correct.

Given, the signal

$$v(t) = 30\sin 100t + 10\cos 300t + 6\sin\left(500t + \tfrac{\pi}{4}\right)$$

So we have

$$\omega_1 = 100\,\text{rad/s}$$
$$\omega_2 = 300\,\text{rad/s}$$
$$\omega_3 = 500\,\text{rad/s}$$

Therefore, the respective time periods are

$$T_1 = \frac{2\pi}{\omega_1} = \frac{2\pi}{100}\text{sec}$$
$$T_2 = \frac{2\pi}{\omega_2} = \frac{2\pi}{300}\text{sec}$$
$$T_3 = \frac{2\pi}{500}\text{sec}$$

So, the fundamental time period of the signal is

$$\text{L.C.M.}\ (T_1, T_2\, T_3) = \frac{LCM(2\pi, 2\pi, 2\pi)}{HCF(100, 300, 500)}$$

or,
$$T_0 = \frac{2\pi}{100}$$

Thus, the fundamental frequency in rad/sec is

$$\omega_0 = \frac{2\pi}{10} = 100\,\text{rad/s}$$

SOL 1.3.3 Option (C) is correct.

If the two systems with impulse response $h_1(t)$ and $h_2(t)$ are connected in cascaded configuration as shown in figure, then the overall response of the system is the convolution of the individual impulse responses.

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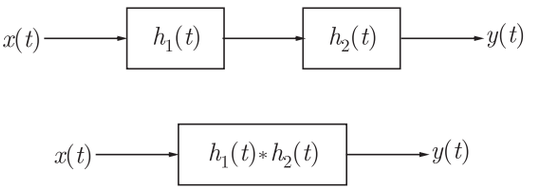

SOL 1.3.4 Option (C) is correct.

For a system to be casual, the R.O.C of system transfer function $H(s)$ which is rational should be in the right half plane and to the right of the right most pole.

For the stability of LTI system. All poles of the system should lie in the left half of S-plane and no repeated pole should be on imaginary axis. Hence, options (A), (B), (D) satisfies both stability and causality an LTI system.

But, Option (C) is not true for the stable system as, $|S|=1$ have one pole in right hand plane also.

SOL 1.3.5 Option (C) is correct.

Given, the input

$$x(t)=u(t-1)$$

It's Laplace transform is

$$X(s)=\frac{e^{-s}}{s}$$

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The impulse response of system is given

$$h(t)=t\,u(t)$$

Its Laplace transform is

$$H(s)=\frac{1}{s^2}$$

Hence, the overall response at the output is

$$Y(s)=X(s)H(s)$$
$$=\frac{e^{-s}}{s^3}$$

its inverse Laplace transform is

$$y(t)=\frac{(t-1)^2}{2}u(t-1)$$

SOL 1.3.6 Option (B) is correct.

Given, the impulse response of continuous time system

$$h(t)=\delta(t-1)+\delta(t-3)$$

From the convolution property, we know

$$x(t)*\delta(t-t_0)=x(t-t_0)$$

So, for the input

$$x(t)=u(t)\ (\text{Unit step fun}^n)$$

The output of the system is obtained as

$$y(t)=u(t)*h(t)$$
$$=u(t)*[\delta(t-1)+\delta(t-3)]$$
$$=u(t-1)+u(t-3)$$

at $t=2$

$$y(2)=u(2-1)+u(2-3)$$

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$= 1$

SOL 1.3.7 Option (C) is correct.

$$x[n] = \left(\frac{1}{3}\right)^{|n|} - \left(\frac{1}{2}\right)^n u[n]$$

$$= \left(\frac{1}{3}\right)^n u[n] + \left(\frac{1}{3}\right)^{-n} u[-n-1] - \left(\frac{1}{2}\right)^n u(n)$$

Taking z-transform

$$X[z] = \sum_{n=-\infty}^{\infty} \left(\frac{1}{3}\right)^n z^{-n} u[n] + \sum_{n=-\infty}^{\infty} \left(\frac{1}{3}\right)^{-n} z^{-n} u[-n-1]$$

$$- \sum_{n=-\infty}^{\infty} \left(\frac{1}{2}\right)^n z^{-n} u[n] = \sum_{n=0}^{\infty} \left(\frac{1}{3}\right)^n z^{-n} + \sum_{n=-\infty}^{-1} \left(\frac{1}{3}\right)^{-n} z^{-n} - \sum_{n=0}^{\infty} \left(\frac{1}{2}\right)^n z^{-n}$$

$$= \underbrace{\sum_{n=0}^{\infty} \left(\frac{1}{3z}\right)^n}_{\text{I}} + \underbrace{\sum_{m=1}^{\infty} \left(\frac{1}{3}z\right)^m}_{\text{II}} - \underbrace{\sum_{n=0}^{\infty} \left(\frac{1}{2z}\right)^n}_{\text{III}} \qquad \text{Taking } m = -n$$

Series I converges if $\left|\frac{1}{3z}\right| < 1$ or $|z| > \frac{1}{3}$

Series II converges if $\left|\frac{1}{3}z\right| < 1$ or $|z| < 3$

Series III converges if $\left|\frac{1}{2z}\right| < 1$ or $|z| > \frac{1}{2}$

Region of convergence of $X(z)$ will be intersection of above three

So, $\text{ROC} : \frac{1}{2} < |z| < 3$

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SOL 1.3.8 Option (D) is correct.

Using s-domain differentiation property of Laplace transform.

If $f(t) \xleftrightarrow{\mathcal{L}} F(s)$

$$tf(t) \xleftrightarrow{\mathcal{L}} -\frac{dF(s)}{ds}$$

So, $$\mathcal{L}[tf(t)] = \frac{-d}{ds}\left[\frac{1}{s^2+s+1}\right] = \frac{2s+1}{(s^2+s+1)^2}$$

SOL 1.3.9 Option (A) is correct.

Convolution sum is defined as

$$y[n] = h[n] * g[n] = \sum_{k=-\infty}^{\infty} h[n]g[n-k]$$

For causal sequence, $$y[n] = \sum_{k=0}^{\infty} h[n]g[n-k]$$

$$y[n] = h[n]g[n] + h[n]g[n-1] + h[n]g[n-2] + ...$$

For $n = 0$, $$y[0] = h[0]g[0] + h[1]g[-1] + ...$$

$$= h[0]g[0] \qquad g[-1] = g[-2] = ...0$$

$$= h[0]g[0] \qquad ...(i)$$

For $n = 1$, $$y[1] = h[1]g[1] + h[1]g[0] + h[1]g[-1] + ...$$

$$= h[1]g[1] + h[1]g[0]$$

$$\frac{1}{2} = \frac{1}{2}g[1] + \frac{1}{2}g[0] \qquad h[1] = \left(\frac{1}{2}\right)^1 = \frac{1}{2}$$

$$1 = g[1] + g[0]$$

$$g[1] = 1 - g[0]$$

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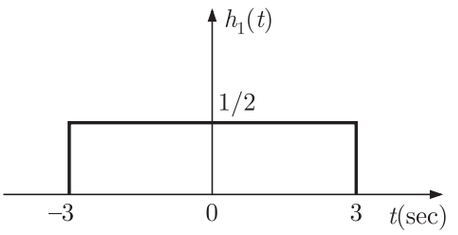
From equation (i), $g[0] = \frac{y[0]}{h[0]} = \frac{1}{1} = 1$

So, $g[1] = 1 - 1 = 0$

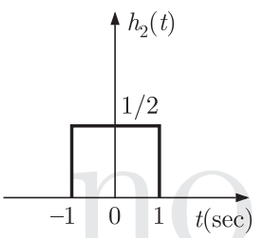
SOL 1.3.10 Option (C) is correct.

$$H(j\omega) = \frac{(2\cos\omega)(\sin 2\omega)}{\omega} = \frac{\sin 3\omega}{\omega} + \frac{\sin\omega}{\omega}$$

We know that inverse Fourier transform of $\sin c$ function is a rectangular function.



$\xleftrightarrow{\mathcal{F}}$ $\frac{\sin 3\omega}{\omega}$



$\xleftrightarrow{\mathcal{F}}$ $\frac{\sin\omega}{\omega}$

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So, inverse Fourier transform of $H(j\omega)$

$$h(t) = h_1(t) + h_2(t)$$

$$h(0) = h_1(0) + h_2(0) = \frac{1}{2} + \frac{1}{2} = 1$$

SOL 1.3.11 Option (D) is correct.

$$y(t) = \int_{-\infty}^{t} x(\tau)\cos(3\tau)\,d\tau$$

Time invariance :

Let, $x(t) = \delta(t)$

$$y(t) = \int_{-\infty}^{t} \delta(t)\cos(3\tau)\,d\tau = u(t)\cos(0) = u(t)$$

For a delayed input $(t - t_0)$ output is

$$y(t, t_0) = \int_{-\infty}^{t} \delta(t - t_0)\cos(3\tau)\,d\tau = u(t)\cos(3t_0)$$

Delayed output

$$y(t - t_0) = u(t - t_0)$$

$$y(t, t_0) \neq y(t - t_0)$$

System is not time invariant.

Stability :

Consider a bounded input $x(t) = \cos 3t$

$$y(t) = \int_{-\infty}^{t} \cos^2 3t = \int_{-\infty}^{t} \frac{1 - \cos 6t}{2} = \frac{1}{2}\int_{-\infty}^{t} 1\,dt - \frac{1}{2}\int_{-\infty}^{t} \cos 6t\,dt$$

As $t \to \infty$, $y(t) \to \infty$ (unbounded)

System is not stable.

SOL 1.3.12 Option (D) is correct.

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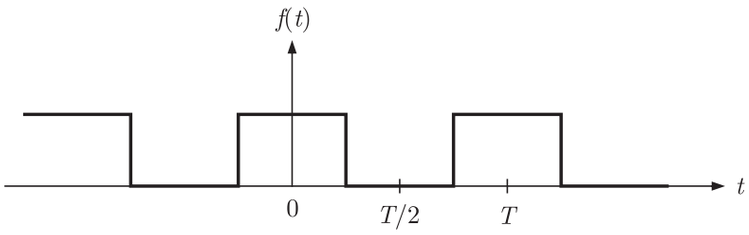

$$f(t) = a_0 + \sum_{n=1}^{\infty}(a_n \cos \omega t + b_n \sin n\omega t)$$

- The given function $f(t)$ is an even function, therefore $b_n = 0$
- $f(t)$ is a non zero average value function, so it will have a non-zero value of a_0

$$a_0 = \frac{1}{(T/2)}\int_0^{T/2} f(t)\,dt \text{ (average value of } f(t))$$

- a_n is zero for all even values of n and non zero for odd n

$$a_n = \frac{2}{T}\int_0^{T} f(t)\cos(n\omega t)\,d(\omega t)$$

So, Fourier expansion of $f(t)$ will have a_0 and a_n, $n = 1,3,5\ldots\infty$

SOL 1.3.13 Option (A) is correct.

$$x(t) = e^{-t}$$

Laplace transformation

$$X(s) = \frac{1}{s+1}$$

$$y(t) = e^{-2t}$$

$$Y(s) = \frac{1}{s+2}$$

Convolution in time domain is equivalent to multiplication in frequency domain.

$$z(t) = x(t) * y(t)$$

$$Z(s) = X(s)\,Y(s) = \left(\frac{1}{s+1}\right)\left(\frac{1}{s+2}\right)$$

By partial fraction and taking inverse Laplace transformation, we get

$$Z(s) = \frac{1}{s+1} - \frac{1}{s+2}$$

$$z(t) = e^{-t} - e^{-2t}$$

SOL 1.3.14 Option (D) is correct.

$$f(t) \xleftrightarrow{\mathcal{L}} F_1(s)$$

$$f(t-\tau) \xleftrightarrow{\mathcal{L}} e^{-s\tau}F_1(s) = F_2(s)$$

$$G(s) = \frac{F_2(s)F_1^*(s)}{|F_1(s)|^2} = \frac{e^{-s\tau}F_1(s)F_1^*(s)}{|F_1(s)|^2}$$

$$= \frac{e^{-sE}|F_1(s)|^2}{|F_1(s)|^2} \qquad \{\because F_1(s)F_1^*(s) = |F_1(s)|^2$$

$$= e^{-s\tau}$$

Taking inverse Laplace transform

$$g(t) = \mathcal{L}^{-1}[e^{-s\tau}] = \delta(t-\tau)$$

SOL 1.3.15 Option (C) is correct.

$$h(t) = e^{-t} + e^{-2t}$$

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Laplace transform of $h(t)$ i.e. the transfer function

$$H(s) = \frac{1}{s+1} + \frac{1}{s+2}$$

For unit step input

$$r(t) = \mu(t)$$

or $$R(s) = \frac{1}{s}$$

Output, $$Y(s) = R(s)H(s) = \frac{1}{s}\left[\frac{1}{s+1} + \frac{1}{s+2}\right]$$

By partial fraction

$$Y(s) = \frac{3}{2s} - \frac{1}{s+1} - \left(\frac{1}{s+2}\right)\frac{1}{2}$$

Taking inverse Laplace

$$y(t) = \frac{3}{2}u(t) - e^{-t}u(t) - \frac{e^{-2t}u(t)}{2}$$

$$= u(t)\left[1.5 - e^{-t} - 0.5e^{-2t}\right]$$

SOL 1.3.16 Option (C) is correct.

System is given as

$$H(s) = \frac{2}{(s+1)}$$

Step input $$R(s) = \frac{1}{s}$$

Output $$Y(s) = H(s)R(s) = \frac{2}{(s+1)}\left(\frac{1}{s}\right) = \frac{2}{s} - \frac{2}{(s+1)}$$

Taking inverse Laplace transform

$$y(t) = (2 - 2e^{-t})u(t)$$

Final value of $y(t)$,

$$y_{ss}(t) = \lim_{t \to \infty} y(t) = 2$$

Let time taken for step response to reach 98% of its final value is t_s.

So,

$$2 - 2e^{-t_s} = 2 \times 0.98$$

$$0.02 = e^{-t_s}$$

$$t_s = \ln 50 = 3.91 \text{ sec.}$$

SOL 1.3.17 Option (D) is correct.

Period of $x(t)$,

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{0.8\pi} = 2.5 \text{ sec}$$

SOL 1.3.18 Option (B) is correct.

Input output relationship

$$y(t) = \int_{-3}^{5t} x(\tau)\,d\tau, \quad t > 0$$

Causality :

$y(t)$ depends on $x(5t), t > 0$ system is non-causal.

For example $t = 2$

$y(2)$ depends on $x(10)$ (future value of input)

Linearity :

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Output is integration of input which is a linear function, so system is linear.

SOL 1.3.19 Option (A) is correct.

Fourier series of given function

$$x(t) = A_0 + \sum_{n=1}^{\infty} a_n \cos n\omega_0 t + b_n \sin n\omega_0 t$$

$$x(t) = -x(t) \text{ odd function}$$

So, $A_0 = 0$

$a_n = 0$

$$b_n = \frac{2}{T}\int_0^T x(t)\sin n\omega_0 t\, dt$$

$$= \frac{2}{T}\left[\int_0^{T/2} (1)\sin n\omega_0 t\, dt + \int_{T/2}^{T} (-1)\sin n\omega_0 t\, dt\right]$$

$$= \frac{2}{T}\left[\frac{\cos n\omega_0 t}{-n\omega_0}\right]_0^{T/2} - \left[\frac{\cos n\omega_0 t}{-n\omega_0}\right]_{T/2}^{T}$$

$$= \frac{2}{n\omega_0 T}\left[(1-\cos n\pi) + (\cos 2n\pi - \cos n\pi)\right]$$

$$= \frac{2}{n\pi}\left[1-(-1)^n\right]$$

$$b_n = \begin{cases} \frac{4}{n\pi}, & n \text{ odd} \\ 0, & n \text{ even} \end{cases}$$

So only odd harmonic will be present in $x(t)$

For second harmonic component $(n = 2)$ amplitude is zero.

SOL 1.3.20 Option (D) is correct.

By parsval's theorem

$$\frac{1}{2\pi}\int_{-\infty}^{\infty} |X(\omega)|^2 d\omega = \int_{-\infty}^{\infty} x^2(t)\, dt$$

$$\int_{-\infty}^{\infty} |X(\omega)|^2 d\omega = 2\pi \times 2 = 4\pi$$

SOL 1.3.21 Option (C) is correct.

Given sequences $x[n] = \underset{\uparrow}{\{1, -1\}}, \quad 0 \le n \le 1$

$$y[n] = \underset{\uparrow}{\{1,0,0,0,-1\}}, \quad 0 \le n \le 4$$

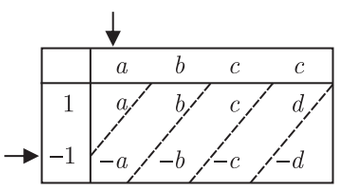
If impulse response is $h[n]$ then

$$y[n] = h[n] * x[n]$$

Length of convolution $(y[n])$ is 0 to 4, $x[n]$ is of length 0 to 1 so length of $h[n]$ will be 0 to 3.

Let $h[n] = \underset{\uparrow}{\{a,b,c,d\}}$

Convolution



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$$y[n] = \{a, -a+b, -b+c, -c+d, -d\}$$

By comparing

$$\begin{aligned} a &= 1 \\ -a+b &= 0 \quad \& \; b = a = 1 \\ -b+c &= 0 \quad \& \; c = b = 1 \\ -c+d &= 0 \quad \& \; d = c = 1 \end{aligned}$$

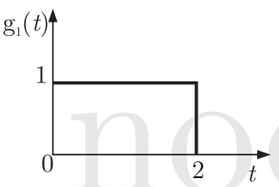
So, $h[n] = \{1,1,1,1\}$

SOL 1.3.22 Option (D) is correct.

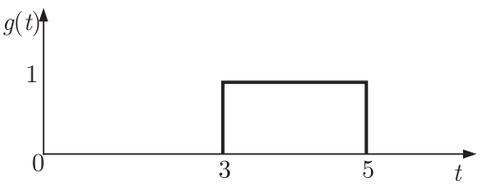
We can observe that if we scale $f(t)$ by a factor of $\frac{1}{2}$ and then shift, we will get $g(t)$.

First scale $f(t)$ by a factor of $\frac{1}{2}$

$$g_1(t) = f(t/2)$$



Shift $g_1(t)$ by 3, $g(t) = g_1(t-3) = f\left(\frac{t-3}{2}\right)$



$$g(t) = f\left(\frac{t}{2} - \frac{3}{2}\right)$$

SOL 1.3.23 Option (C) is correct.

$g(t)$ can be expressed as

$$g(t) = u(t-3) - u(t-5)$$

By shifting property we can write Laplace transform of $g(t)$

$$G(s) = \frac{1}{s}e^{-3s} - \frac{1}{s}e^{-5s} = \frac{e^{-3s}}{s}(1 - e^{-2s})$$

SOL 1.3.24 Option (D) is correct.

Let $x(t) \xleftrightarrow{\mathcal{L}} X(s)$

$y(t) \xleftrightarrow{\mathcal{L}} Y(s)$

$h(t) \xleftrightarrow{\mathcal{L}} H(s)$

So output of the system is given as

$$Y(s) = X(s)H(s)$$

Now for input $x(t-\tau) \xleftrightarrow{\mathcal{L}} e^{-s\tau}X(s)$ (shifting property)

$h(t-\tau) \xleftrightarrow{\mathcal{L}} e^{-s\tau}H(s)$

So now output is $Y'(s) = e^{-s\tau}X(s)\,e^{-\tau s}H(s)$

$$= e^{-2s\tau}X(s)H(s) = e^{-2s\tau}Y(s)$$

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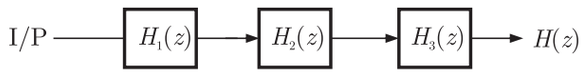
$$y'(t) = y(t - 2\tau)$$

SOL 1.3.25 Option (B) is correct.

Let three LTI systems having response $H_1(z), H_2(z)$ and $H_3(z)$ are Cascaded as showing below



Assume $H_1(z) = z^2 + z^1 + 1$ (non-causal)

$H_2(z) = z^3 + z^2 + 1$ (non-causal)

Overall response of the system

$$H(z) = H_1(z)\,H_2(z)\,H_3(z)$$

$$H(z) = (z^2 + z^1 + 1)(z^3 + z^2 + 1)\,H_3(z)$$

To make $H(z)$ causal we have to take $H_3(z)$ also causal.

Let $H_3(z) = z^{-6} + z^{-4} + 1$

$$= (z^2 + z^1 + 1)(z^3 + z^2 + 1)(z^{-6} + z^{-4} + 1)$$

$H(z) \rightarrow$ causal

Similarly to make $H(z)$ unstable atleast one of the system should be unstable.

SOL 1.3.26 Option (C) is correct.

Given signal

$$x(t) = \sum_{k=-3}^{3} a_k e^{j2\pi kt/T}$$

Let ω_0 is the fundamental frequency of signal $x(t)$

$$x(t) = \sum_{k=-3}^{3} a_k e^{jk\omega_0 t} \qquad \because \frac{2\pi}{T} = \omega_0$$

$$x(t) = a_{-2}e^{-j2\omega_0 t} + a_{-1}e^{-j\omega_0 t} + a_0 + a_1 e^{j\omega_0 t} + a_2 e^{j2\omega_0 t}$$

$$= (2 - j)\,e^{-2j\omega_0 t} + (0.5 + 0.2j)\,e^{-j\omega_0 t} + 2j + (0.5 - 0.2)\,e^{j\omega_0 t} + (2 + j)\,e^{j2\omega_0 t}$$

$$= 2\{e^{-j2\omega_0 t} + e^{j2\omega_0 t}\} + j\{e^{j2\omega_0 t} - e^{-j2\omega_0 t}\} + 0.5\{e^{j\omega_0 t} + e^{-j\omega_0 t}\} - 0.2j\{e^{+j\omega_0 t} - e^{-j\omega_0 t}\} + 2j$$

$$= 2(2\cos 2\omega_0 t) + j(2j\sin 2\omega_0 t) + 0.5(2\cos\omega_0 t) - 0.2j(2j\sin\omega_0 t) + 2j$$

$$= \{4\cos 2\omega_0 t - 2\sin 2\omega_0 t + \cos\omega_0 t + 0.4\sin\omega_0 t\} + 2j$$

$$\text{Im}[x(t)] = 2 \quad \text{(constant)}$$

SOL 1.3.27 Option (A) is correct.

Z-transform of $x[n]$ is

$$X(z) = 4z^{-3} + 3z^{-1} + 2 - 6z^2 + 2z^3$$

Transfer function of the system

$$H(z) = 3z^{-1} - 2$$

Output

$$Y(z) = H(z)\,X(z)$$

$$Y(z) = (3z^{-1} - 2)(4z^{-3} + 3z^{-1} + 2 - 6z^2 + 2z^3)$$

$$= 12z^{-4} + 9z^{-2} + 6z^{-1} - 18z + 6z^2 - 8z^{-3} - 6z^{-1} - 4 + 12z^2 - 4z^3$$

$$= 12z^{-4} - 8z^{-3} + 9z^{-2} - 4 - 18z + 18z^2 - 4z^3$$

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Or sequence $y[n]$ is

$$y[n] = 12\delta[n-4] - 8\delta[n-3] + 9\delta[n-2] - 4\delta[n] - 18\delta[n+1] + 18\delta[n+2] - 4\delta[n+3]$$

$$y[n] \neq 0,\ n < 0$$

So $y[n]$ is non-causal with finite support.

SOL 1.3.28 Option (D) is correct.

Since the given system is LTI, So principal of Superposition holds due to linearity.

For causal system $h(t) = 0,\ t < 0$

Both statement are correct.

SOL 1.3.29 Option (C) is correct.

For an LTI system output is a constant multiplicative of input with same frequency.

Here input $g(t) = e^{-\alpha t}\sin(\omega t)$

output $y(t) = Ke^{-\beta t}\sin(\nu t + \phi)$

Output will be in form of $Ke^{-\alpha t}\sin(\omega t + \phi)$

So $\alpha = \beta, \nu = \omega$

SOL 1.3.30 Option (D) is correct.

Input-output relation

$$y(t) = \int_{-\infty}^{-2t} x(\tau)\,d\tau$$

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Causality :

Since $y(t)$ depends on $x(-2t)$, So it is non-causal.

Time-variance :

$$y(t) = \int_{-\infty}^{-2t} x(\tau - \tau_0)\,d\tau \neq y(t - \tau_0)$$

So this is time-variant.

Stability :

Output $y(t)$ is unbounded for an bounded input.

For example

Let $x(\tau) = e^{-\tau}$ (bounded)

$$y(t) = \int_{-\infty}^{-2t} e^{-\tau}\,d\tau = \left[\frac{e^{-\tau}}{-1}\right]_{-\infty}^{-2t} \quad \text{Unbounded}$$

SOL 1.3.31 Option (A) is correct.

Output $y(t)$ of the given system is

$$y(t) = x(t) * h(t)$$

Or $$Y(j\omega) = X(j\omega)H(j\omega)$$

Given that, $x(t) = \text{sinc}(\alpha t)$ and $h(t) = \text{sinc}(\beta t)$

Fourier transform of $x(t)$ and $h(t)$ are

$$X(j\omega) = \mathcal{F}[x(t)] = \frac{\pi}{\alpha}\text{rect}\left(\frac{\omega}{2\alpha}\right), -\alpha < \omega < \alpha$$

$$H(j\omega) = \mathcal{F}[h(t)] = \frac{\pi}{\beta}\text{rect}\left(\frac{\omega}{2\beta}\right), -\beta < \omega < \beta$$

$$Y(j\omega) = \frac{\pi^2}{\alpha\beta}\text{rect}\left(\frac{\omega}{2\alpha}\right)\text{rect}\left(\frac{\omega}{2\beta}\right)$$

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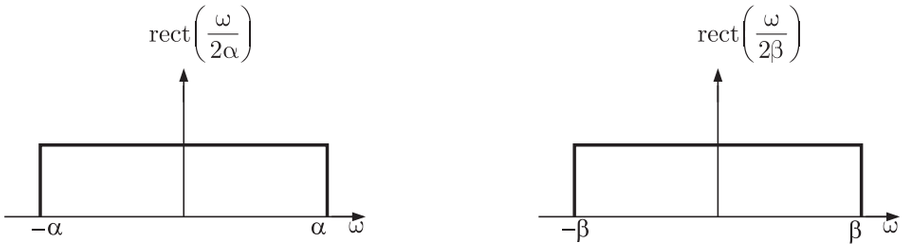

So, $Y(j\omega) = K \text{ rect } \left(\frac{\omega}{2\gamma}\right)$

Where $\gamma = \min(\alpha, \beta)$

And $y(t) = K \text{ sinc}(\gamma t)$

SOL 1.3.32 Option (B) is correct.

Let a_k is the Fourier series coefficient of signal $x(t)$

Given $y(t) = x(t - t_0) + x(t + t_0)$

Fourier series coefficient of $y(t)$

$$b_k = e^{-jk\omega t_0} a_k + e^{jk\omega t_0} a_k$$

$$b_k = 2a_k \cos k\omega t_0$$

$$b_k = 0 \text{ (for all odd } k)$$

$$k\omega t_0 = \frac{\pi}{2}, \text{ k} \to \text{odd}$$

$$k\frac{2\pi}{T} t_0 = \frac{\pi}{2}$$

For $k = 1$, $t_0 = \frac{T}{4}$

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SOL 1.3.33 Option ( ) is correct.

SOL 1.3.34 Option (D) is correct.

Given that $X(z) = \frac{z}{(z-a)^2}, \; |z| > a$

Residue of $X(z)z^{n-1}$ at $z = a$ is

$$= \frac{d}{dz}(z-a)^2 X(z) z^{n-1}\Big|_{z=a}$$

$$= \frac{d}{dz}(z-a)^2 \frac{z}{(z-a)^2} z^{n-1}\Big|_{z=a}$$

$$= \frac{d}{dz} z^n\Big|_{z=a} = nz^{n-1}\Big|_{z=a} = na^{n-1}$$

SOL 1.3.35 Option (C) is correct.

Given signal

$$x(t) = \text{rect}\left(t - \frac{1}{2}\right)$$

So, $$x(t) = \begin{cases} 1, & -\frac{1}{2} \# t - \frac{1}{2} \# \frac{1}{2} \text{ or } 0 \# t \# 1 \\ 0, & \text{elsewhere} \end{cases}$$

Similarly

$$x(-t) = \text{rect}\left(-t - \frac{1}{2}\right)$$

$$x(-t) = \begin{cases} 1, & -\frac{1}{2} \# -t - \frac{1}{2} \# \frac{1}{2} \text{ or } -1 \# t \# 0 \\ 0, & \text{elsewhere} \end{cases}$$

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$$\mathcal{F}[x(t)+x(-t)] = \int_{-3}^{3} x(t)e^{-j\omega t}dt + \int_{-3}^{3} x(-t)e^{-j\omega t}dt$$

$$= \int_{0}^{1}(1)e^{-j\omega t}dt + \int_{-1}^{0}(1)e^{-j\omega t}dt$$

$$= \left[\frac{e^{-j\omega t}}{-j\omega}\right]_{0}^{1} + \left[\frac{e^{-j\omega t}}{-j\omega}\right]_{-1}^{0} = \frac{1}{j\omega}(1-e^{-j\omega}) + \frac{1}{j\omega}(e^{j\omega}-1)$$

$$= \frac{e^{-j\omega/2}}{j\omega}(e^{j\omega/2}-e^{-j\omega/2}) + \frac{e^{j\omega/2}}{j\omega}(e^{j\omega/2}-e^{-j\omega/2})$$

$$= \frac{(e^{j\omega/2}-e^{-j\omega/2})(e^{-j\omega/2}+e^{j\omega/2})}{j\omega}$$

$$= \frac{2}{\omega}\sin\left(\frac{\omega}{2}\right)\cdot 2\cos\left(\frac{\omega}{2}\right) = 2\cos\frac{\omega}{2}\,\text{sinc}\left(\frac{\omega}{2\pi}\right)$$

SOL 1.3.36 Option (B) is correct.

In option (A)

$$z_1[n] = x[n-3]$$
$$z_2[n] = z_1[4n] = x[4n-3]$$
$$y[n] = z_2[-n] = x[-4n-3] \neq x[3-4n]$$

In option (B)

$$z_1[n] = x[n+3]$$
$$z_2[n] = z_1[4n] = x[4n+3]$$
$$y[n] = z_2[-n] = x[-4n+3]$$

In option (C)

$$v_1[n] = x[4n]$$
$$v_2[n] = v_1[-n] = x[-4n]$$
$$y[n] = v_2[n+3] = x[-4(n+3)] \neq x[3-4n]$$

In option (D)

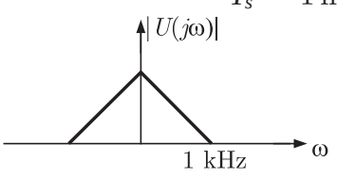
$$v_1[n] = x[4n]$$
$$v_2[n] = v_1[-n] = x[-4n]$$
$$y[n] = v_2[n-3] = x[-4(n-3)] \neq x[3-4n]$$

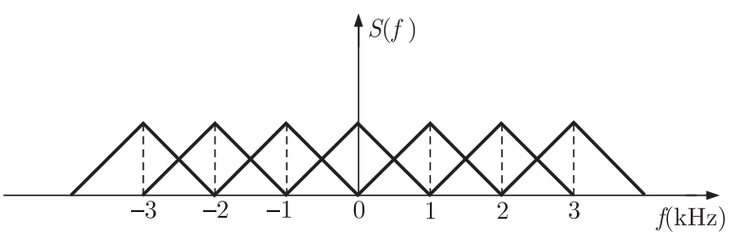
SOL 1.3.37 Option ( ) is correct.

The spectrum of sampled signal $s(j\omega)$ contains replicas of $U(j\omega)$ at frequencies $\pm nf_s$.

Where $n = 0,1,2.....$

$$f_s = \frac{1}{T_s} = \frac{1}{1\,\text{m sec}} = 1\,\text{kHz}$$





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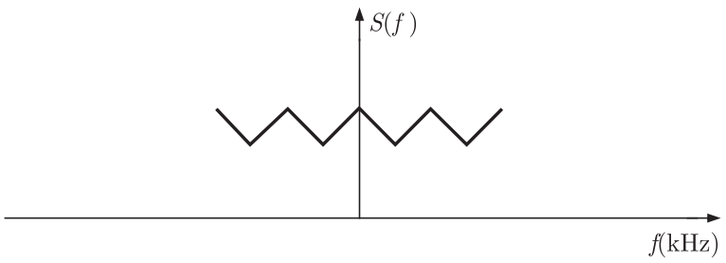


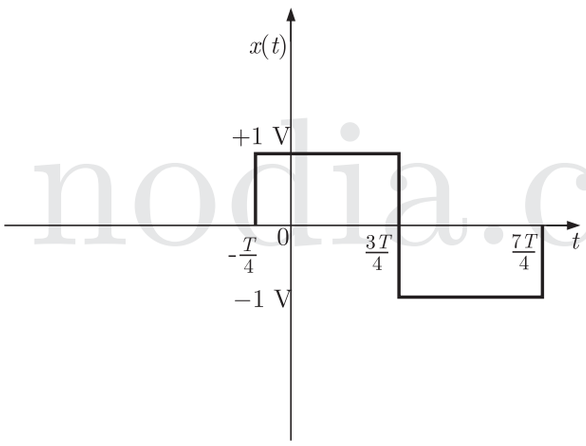
SOL 1.3.38 Option (D) is correct.

For an LTI system input and output have identical wave shape (i.e. frequency of input-output is same) within a multiplicative constant (i.e. Amplitude response is constant)

So F must be a sine or cosine wave with $\omega_1 = \omega_2$

SOL 1.3.39 Option (C) is correct.

Given signal has the following wave-form



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Function x(t) is periodic with period $2T$ and given that

$$x(t) = -x(t+T) \text{ (Half-wave symmetric)}$$

So we can obtain the fourier series representation of given function.

SOL 1.3.40 Option (C) is correct.

Output is said to be distortion less if the input and output have identical wave shapes within a multiplicative constant. A delayed output that retains input waveform is also considered distortion less.

Thus for distortion less output, input-output relationship is given as

$$y(t) = Kg(t - t_d)$$

Taking Fourier transform.

$$Y(\omega) = KG(\omega)e^{-j\omega t_d} = G(\omega)H(\omega)$$

$H(\omega)$ & transfer function of the system

So, $H(\omega) = Ke^{-j\omega t_d}$

Amplitude response $|H(\omega)| = K$

Phase response, $\theta_n(\omega) = -\omega t_d$

For distortion less output, phase response should be proportional to frequency.

SOL 1.3.41 Option (A) is correct.

$$G(z)\big|_{z=e^{j\omega}} = \alpha e^{-j\omega} + \beta e^{-3j\omega}$$

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for linear phase characteristic $\alpha = \beta$.

SOL 1.3.42 Option (A) is correct.

System response is given as

$$H(z) = \frac{G(z)}{1 - KG(z)}$$

$$g[n] = \delta[n-1] + \delta[n-2]$$

$$G(z) = z^{-1} + z^{-2}$$

So $$H(z) = \frac{(z^{-1} + z^{-2})}{1 - K(z^{-1} + z^{-2})} = \frac{z+1}{z^2 - Kz - K}$$

For system to be stable poles should lie inside unit circle.

$$|z| \# 1$$

$$z = \frac{K \pm \sqrt{K^2 + 4K}}{2} \# 1 \quad K \pm \sqrt{K^2 + 4K} \# 2$$

$$\sqrt{K^2 + 4K} \# 2 - K$$

$$K^2 + 4K \# 4 - 4K + K^2$$

$$8K \# 4$$

$$K \# 1/2$$

SOL 1.3.43 Option (C) is correct.

Given Convolution is,

$$h(t) = u(t+1) \cdot r(t-2)$$

Taking Laplace transform on both sides,

$$H(s) = \mathcal{L}[h(t)] = \mathcal{L}[u(t+1)] \cdot \mathcal{L}[r(t-2)]$$

We know that, $\mathcal{L}[u(t)] = 1/s$

$$\mathcal{L}[u(t+1)] = e^{s}\left(\frac{1}{s^2}\right) \quad \text{(Time-shifting property)}$$

and $$\mathcal{L}[r(t)] = 1/s^2$$

$$\mathcal{L}\, r(t-2) = e^{-2s}\left(\frac{1}{s^2}\right) \quad \text{(Time-shifting property)}$$

So $$H(s) = \left(e^{s} \cdot \frac{1}{s}\right)\left(e^{-2s}\left(\frac{1}{s^2}\right)\right)$$

$$H(s) = e^{-s}\left(\frac{1}{s^3}\right)$$

Taking inverse Laplace transform

$$h(t) = \frac{1}{2}(t-1)^2 u(t-1)$$

SOL 1.3.44 Option (C) is correct.

Impulse response of given LTI system.

$$h[n] = x[n-1] * y[n]$$

Taking z-transform on both sides.

$$H(z) = z^{-1} X(z)\, Y(z)$$

a $x[n-1] \xleftrightarrow{\mathcal{Z}} z^{-1}x(z)$

We have $X(z) = 1 - 3z^{-1}$ and $Y(z) = 1 + 2z^{-2}$

So

$$H(z) = z^{-1}(1 - 3z^{-1})(1 + 2z^{-2})$$

Output of the system for input $u[n] = \delta[n-1]$ is,

$$y(z) = H(z)\,U(z)$$

$$U[n] \xleftrightarrow{\mathcal{Z}} U(z) = z^{-1}$$

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So

$$Y(z) = z^{-1}(1-3z^{-1})(1+2z^{-2})z^{-1}$$
$$= z^{-2}(1-3z^{-1}+2z^{-2}-6z^{-3}) = z^{-2}-3z^{-3}+2z^{-4}-6z^{-5}$$

Taking inverse z-transform on both sides we have output.

$$y[n] = \delta[n-2]-3\delta[n-3]+2\delta[n-4]-6\delta[n-5]$$

SOL 1.3.45 Option (B) is correct.

A bounded signal always possesses some finite energy.

$$E = \int_{-t_0}^{t_0} |g(t)^2| dt < \infty$$

SOL 1.3.46 Option (C) is correct.

Trigonometric Fourier series is given as

$$x(t) = A_0 + \sum_{n=1}^{\infty} a_n \cos n\omega_0 t + b_n \sin n\omega_0 t$$

Since there are no sine terms, so $b_n = 0$

$$b_n = \frac{2}{T_0}\int_0^{T_0} x(t)\sin n\omega_0 t\, dt$$
$$= \frac{2}{T_0}\left[\int_0^{T_0/2} x(\tau)\sin n\omega_0\tau\, d\tau + \int_{T_0/2}^{T} x(t)\sin n\omega_0 t\, dt\right]$$

Where $\tau = T - t \quad \& \quad d\tau = -dt$

$$= \frac{2}{T_0}\left[\int_{T_0}^{T_0/2} x(T-t)\sin n\omega_0(T-t)(-dt) + \int_{T_0/2}^{T} x(t)\sin n\omega_0 t\, dt\right]$$
$$= \frac{2}{T_0}\left[\int_{T_0/2}^{T_0} x(T-t)\sin n\left(\frac{2\pi}{T}T - t\right)dt + \int_{T_0/2}^{T} x(t)\sin n\omega_0 t\, dt\right]$$
$$= \frac{2}{T_0}\left[\int_{T_0/2}^{T_0} x(T-t)\sin(2n\pi - n\omega_0)dt + \int_{T_0/2}^{T_0} x(t)\sin n\omega_0 t\, dt\right]$$
$$= \frac{2}{T_0}\left[-\int_{T_0/2}^{T_0} x(T-t)\sin(n\omega_0 t)\,dt + \int_{T_0/2}^{T_0} x(t)\sin n\omega_0 t\, dt\right]$$

$b_n = 0$ if $x(t) = x(T-t)$

From half wave symmetry we know that if

$$x(t) = -x\left(t \pm \frac{T}{2}\right)$$

Then Fourier series of $x(t)$ contains only odd harmonics.

SOL 1.3.47 Option (C) is correct.

Z-transform of a discrete all pass system is given as

$$H(z) = \frac{z^{-1} - z_0^*}{1 - z_0 z^{-1}}$$

It has a pole at z_0 and a zero at $1/z_0^*$.

Given system has a pole at

$$z = 2\angle 30^\circ = 2\frac{(\sqrt{3}+j)}{2} = (\sqrt{3}+j)$$

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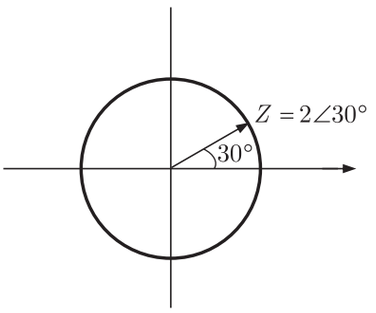

system is stable if $|z| < 1$ and for this it is anti-causal.

SOL 1.3.48 Option (A) is correct.

According to given data input and output Sequences are

$$x[n] = \{-1, \underset{\text{-}}{2}\}, -1 \# n \# 0$$

$$y[n] = \{-1, \underset{\text{-}}{3}, -1, -2\}, -1 \# n \# 2$$

If impulse response of system is $h[n]$ then output

$$y[n] = h[n] \circledast x[n]$$

Since length of convolution ($y[n]$) is -1 to 2, $x[n]$ is of length -1 to 0 so length of $h[n]$ is 0 to 2.

Let $h[n] = \{\underset{\text{-}}{a}, b, c\}$

Convolution

	a	b	c
-1	$-a$	$-b$	$-c$
2	$2a$	$2b$	$2c$

$$y[n] = \{-a, 2a - b, 2b - c, 2c\}$$

$$y[n] = \{-1, \underset{\text{-}}{3}, -1, -2\}$$

So,

$a = 1$

$2a - b = 3 \quad \& \; b = -1$

$2a - c = -1 \quad \& \; c = -1$

Impulse response $h[n] = \{\underset{\text{-}}{1}, -1, -1\}$

SOL 1.3.49 Option ( ) is correct.

SOL 1.3.50 Option (D) is correct.

Output $y(t) = e^{-|x(t)|}$

If $x(t)$ is unbounded, $|x(t)| \to \infty$

$$y(t) = e^{-|x(t)|} \to 0 \quad \text{(bounded)}$$

So $y(t)$ is bounded even when $x(t)$ is not bounded.

SOL 1.3.51 Option (B) is correct.

Given $y(t) = \int_{-\infty}^{t} x(t')\,dt'$

Laplace transform of $y(t)$

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$$Y(s) = \frac{X(s)}{s}, \text{ has a singularity at } s = 0$$

For a causal bounded input, $y(t) = \int_{-\infty}^{t} x(t')\,dt'$ is always bounded.

SOL 1.3.52 Option (A) is correct.

RMS value is given by

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T V^2(t)\,dt}$$

Where

$$V(t) = \begin{cases} \frac{2}{T}t, & 0 \le t \le \frac{T}{2} \\ 0, & \frac{T}{2} < t \le T \end{cases}$$

So
$$\frac{1}{T}\int_0^T V^2(t)\,dt = \frac{1}{T}\left[\int_0^{T/2}\left(\frac{2t}{T}\right)^2 dt + \int_{T/2}^{T}(0)\,dt\right]$$

$$= \frac{1}{T}\left(\frac{4}{T^2}\int_0^{T/2} t^2\,dt\right) = \frac{4}{T^3}\left(\frac{t^3}{3}\right)_0^{T/2}$$

$$= \frac{4}{T^3}\cdot\frac{T^3}{24} = \frac{1}{6}$$

$$V_{rms} = \sqrt{\frac{1}{6}}\ \text{V}$$

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SOL 1.3.53 Option (A) is correct.

By final value theorem

$$\lim_{t\to\infty} f(t) = \lim_{s\to 0} s\,F(s) = \lim_{s\to 0} s\,\frac{(5s^2+23s+6)}{s(s^2+2s+2)}$$

$$= \frac{6}{2} = 3$$

SOL 1.3.54 Option (D) is correct.

$$f(x) = \sin^2 x = \frac{1-\cos 2x}{2}$$

$$= 0.5 - 0.5\cos 2x$$

$$f(x) = A_0 + \sum_{n=1}^{\infty} a_n \cos n\omega_0 x + b_n \sin n\omega_0 x$$

$f(x) = \sin^2 x$ is an even function so $b_n = 0$

$$A_0 = 0.5$$

$$a_n = \begin{cases} -0.5, & n = 1 \\ 0, & \text{otherwise} \end{cases}$$

$$\omega_0 = \frac{2\pi}{T_0} = \frac{2\pi}{T} = 2$$

SOL 1.3.55 Option (B) is correct.

Z-transform $F(z) = \frac{1}{z+1} = 1 - \frac{z}{z+1} = 1 - \frac{1}{1+z^{-1}}$

so, $f(k) = \delta(k) - (-1)^k$

Thus $(-1)^k \xleftrightarrow{\mathcal{Z}} \frac{1}{1+z^{-1}}$

SOL 1.3.56 Option (A) is correct.

Root mean square value is given as

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T I^2(t)\,dt}$$

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From the graph, $I(t) = \begin{cases} -\left(\frac{12}{T}\right)t, & 0 \le t < \frac{T}{2} \\ 6, & T/2 < t \le T \end{cases}$

So $$\frac{1}{T}\int_0^T I^2 dt = \frac{1}{T}\left[\int_0^{T/2}\left(\frac{-12t}{T}\right)^2 dt + \int_{T/2}^{T}(6)^2 dt\right]$$

$$= \frac{1}{T}\left[\frac{144}{T^2}\cdot\frac{t^3}{3}\right]_0^{T/2} + 36\left[t\right]_{T/2}^{T}$$

$$= \frac{1}{T}\cdot\frac{144}{T^2}\left[\frac{T^3}{24}\right] + 36\left(\frac{T}{2}\right) = \frac{1}{T}[6T + 18T] = 24$$

$$I_{rms} = \sqrt{24} = 2\sqrt{6}\ \text{A}$$

SOL 1.3.57 Option (B) is correct.

Total current in wire

$$I = 10 + 20\sin\omega t$$

$$I_{rms} = \sqrt{(10)^2 + \frac{(20)^2}{2}} = 17.32\ \text{A}$$

SOL 1.3.58 Option (C) is correct.

Fourier series representation is given as

$$f(t) = A_0 + \sum_{n=1}^{\infty} a_n \cos n\omega_0 t + b_n \sin n\omega_0 t$$

From the wave form we can write fundamental period T = 2 sec

$$f(t) = \begin{cases} \left(\frac{4}{T}\right)t, & -\frac{T}{2} \le t \le 0 \\ -\left(\frac{4}{T}\right)t, & 0 \le t \le \frac{T}{2} \end{cases}$$

$f(t) = f(-t)$, $f(t)$ is an even function

So, $b_n = 0$

$$A_0 = \frac{1}{T}\int_T f(t)\,dt$$

$$= \frac{1}{T}\left[\int_{-T/2}^{0}\left(\frac{4}{T}\right)t\,dt + \int_0^{T/2}\left(-\frac{4}{T}\right)t\,dt\right]$$

$$= \frac{1}{T}\left[\frac{4}{T}\cdot\frac{t^2}{2}\right]_{-T/2}^{0} - \frac{4}{T}\cdot\frac{t^2}{2}\Big]_0^{T/2}$$

$$= \frac{1}{T}\cdot\frac{4}{T}\left[\frac{T^2}{8}\right] - \frac{4}{T}\left[\frac{T^2}{8}\right] = 0$$

$$a_n = \frac{2}{T}\int_T f(t)\cos n\omega_0 t\,dt$$

$$= \frac{2}{T}\left[\int_{-T/2}^{0}\left(\frac{4}{T}\right)t\cos n\omega_0 t + \int_0^{T/2}\left(-\frac{4}{T}\right)t\cos n\omega_0 t\,dt\right]$$

By solving the integration

$$a_n = \begin{cases} \frac{8}{n^2\pi^2}, & n \text{ is odd} \\ 0, & n \text{ is even} \end{cases}$$

So,

$$f(t) = \frac{8}{\pi^2}\left[\cos\pi t + \frac{1}{9}\cos(3\pi t) + \frac{1}{25}\cos(5\pi t) + \ldots.\right]$$

SOL 1.3.59 Option (A) is correct.

Response for any input $u(t)$ is given as

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$$y(t) = u(t) \rangle h(t) \qquad h(t) \text{ " impulse response}$$

$$y(t) = \int_{-3}^{3} u(\tau) h(t-\tau)\, d\tau$$

Impulse response $h(t)$and step response $s(t)$ of a system is related as

$$h(t) = \frac{d}{dt}[s(t)]$$

So $$y(t) = \int_{-3}^{3} u(\tau) \frac{d}{dt} s[t-\tau]\, d\tau = \frac{d}{dt} \int_{-3}^{3} u(\tau) s(t-\tau)\, d\tau$$

SOL 1.3.60 Option (B) is correct.

Final value theorem states that

$$\lim_{t \to \infty} y(t) \quad \lim_{s \to \infty} Y(s)$$

SOL 1.3.61 Option (D) is correct.

$$V_{rms} = \sqrt{\frac{1}{T_0} \int_{T_0} V^2(t)\, dt}$$

here $T_0 = \pi$

$$\frac{1}{T_0} \int_{T_0} V^2(t)\, dt = \frac{1}{\pi} \left[\int_{0}^{\pi/3} (100)^2 dt + \int_{\pi/3}^{2\pi/3} (-100)^2 dt + \int_{2\pi/3}^{\pi} (100)^2 dt \right]$$

$$= \frac{1}{\pi} \left[10^4 \left(\frac{\pi}{3} \right) + 10^4 \left(\frac{\pi}{3} \right) + 10^4 \left(\frac{\pi}{3} \right) \right] = 10^4 \text{ V}$$

$$V_{rms} = \sqrt{10^4} = 100 \text{ V}$$

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SOL 1.3.62 Option (D) is correct.

Let $h(t)$ is the impulse response of system

$$y(t) = u(t) \rangle h(t)$$

$$y(t) = \int_{0}^{t} u(\tau) h(t-\tau)\, d\tau$$

$$= \int_{0}^{t} (2 + t - \tau) e^{-3(t-\tau)} u(\tau)\, d\tau$$

So $$h(t) = (t+2) e^{-3t} u(t), t > 0$$

Transfer function

$$H(s) = \frac{Y(s)}{U(s)} = \frac{1}{(s+3)^2} + \frac{2}{(s+3)}$$

$$= \frac{1 + 2s + 6}{(s+3)^2} = \frac{(2s+7)}{(s+3)^2}$$

SOL 1.3.63 Option (B) is correct.

Fourier series representation is given as

$$v(t) = A_0 + \sum_{n=1}^{\infty} a_n \cos n\omega_0 t + b_n \sin n\omega_0 t$$

period of given wave form $T = 5$ ms

DC component of v is

$$A_0 = \frac{1}{T} \int_{T} v(t)\, dt$$

$$= \frac{1}{5} \left[\int_{0}^{3} 1\, dt + \int_{3}^{5} -1\, dt \right]$$

$$= \frac{1}{5} [3 - 5 + 3] = \frac{1}{5}$$

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SOL 1.3.64 Option (A) is correct.

$$\text{Coefficient}, a_n = \frac{2}{T}\oint_T v(t)\cos n\omega_0 t\, dt$$

$$= \frac{2}{5}\left[\int_0^3 (1)\cos nwt\, dt + \int_3^5 (-1)\cos nwt\, dt\right]$$

$$= \frac{2}{5}\left(\left[\frac{\sin n\omega t}{n\omega}\right]_0^3 - \left[\frac{\sin n\omega t}{n\omega}\right]_3^5\right)$$

Put $\omega = \frac{2\pi}{T} = \frac{2\pi}{5}$

$$a_n = \frac{1}{n\pi}[\sin 3n\omega - \sin 5n\omega + \sin 3n\omega]$$

$$= \frac{1}{n\pi}\left[2\sin\left(3n\frac{2\pi}{5}\right) - \sin\left(5n\frac{2\pi}{5}\right)\right]$$

$$= \frac{1}{n\pi}\left[2\sin\left(\frac{6\pi n}{5}\right) - \sin(2n\pi)\right]$$

$$= \frac{2}{n\pi}\sin\left(\frac{6\pi n}{5}\right)$$

$$\text{Coefficient, } b_n = \frac{2}{T}\oint_T v(t)\sin n\omega_0 t\, dt$$

$$= \frac{2}{5}\left[\int_0^3 (1)\sin nwt\, dt + \int_3^5 (-1)\sin nwt\, dt\right]$$

$$= \frac{2}{5}\left(\left[-\frac{\cos n\omega t}{n\omega}\right]_0^3 - \left[-\frac{\cos n\omega t}{n\omega}\right]_3^5\right)$$

put $\omega = \frac{2\pi}{T} = \frac{2\pi}{5}$

$$b_n = \frac{1}{n\pi}[-\cos 3n\omega + 1 + \cos 5n\omega - \cos 3n\omega]$$

$$= \frac{1}{n\pi}[-2\cos 3n\omega + 1 + \cos 5n\omega]$$

$$= \frac{1}{n\pi}\left[-2\cos\left(3n\frac{2\pi}{5}\right) + 1 + \cos\left(5n\frac{2\pi}{5}\right)\right]$$

$$= \frac{1}{n\pi}\left[-2\cos\left(\frac{6\pi n}{5}\right) + 1 + 1\right]$$

$$= \frac{2}{n\pi}\left[1 - \cos\left(\frac{6\pi n}{5}\right)\right]$$

Amplitude of fundamental component of v is

$$v_f = \sqrt{a_1^2 + b_1^2}$$

$$a_1 = \frac{2}{\pi}\sin\left(\frac{6\pi}{5}\right),\ b_1 = \frac{2}{\pi}\left(1 - \cos\frac{6\pi}{5}\right)$$

$$v_f = \frac{2}{\pi}\sqrt{\sin^2\frac{6\pi}{5} + \left(1 - \cos\frac{6\pi}{5}\right)^2}$$

$$= 1.20 \text{ Volt}$$

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4

ELECTRICAL MACHINES

YEAR 2013 — ONE MARK

MCQ 1.4.1 Leakage flux in an induction motor is

(A) flux that leaks through the machine

(B) flux that links both stator and rotor windings

(C) flux that links none of the windings

(D) flux that links the stator winding or the rotor winding but not both

MCQ 1.4.2 The angle δ in the swing equation of a synchronous generator is the

(A) angle between stator voltage and current

(B) angular displacement of the rotor with respect to the stator

(C) angular displacement of the stator mmf with respect to a synchronously rotating axis.

(D) angular displacement of an axis fixed to the rotor with respect to a synchronously rotating axis

MCQ 1.4.3 A single-phase transformer has no-load loss of 64 W, as obtained from an open circuit test. When a short-circuit test is performed on it with 90% of the rated currents flowing in its both LV and HV windings, he measured loss is 81 W. The transformer has maximum efficiency when operated at

(A) 50.0% of the rated current (B) 64.0% of the rated current

(C) 80.0% of the rated current (D) 88.8% of the rated current

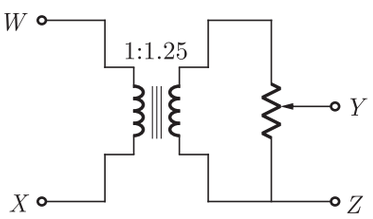
YEAR 2013 — TWO MARKS

MCQ 1.4.4 A 4-pole induction motor, supplied by a slightly unbalanced three-phase 50 Hz source, is rotating at 1440 rpm. The electrical frequency in Hz of the induced negative sequence current in the rotor is

(A) 100 (B) 98

(C) 52 (D) 48

MCQ 1.4.5 The following arrangement consists of an ideal transformer and an attenuator which attenuates by a factor of 0.8. An ac voltage $V_{WX1} = 100\,\text{V}$ is applied across WX to get an open circuit voltage V_{YZ1} across YZ. Next, an ac voltage $V_{YZ2} = 100\,\text{V}$ is applied across YZ to get an open circuit voltage V_{WX2} across WX. Then, V_{YZ1}/V_{WX1}, V_{WX2}/V_{YZ2} are respectively,



(A) 125/100 and 80/100 (B) 100/100 and 80/100
(C) 100/100 and 100/100 (D) 80/100 and 80/100

YEAR 2012 ONE MARK

MCQ 1.4.6 The slip of an induction motor normally does not depend on
(A) rotor speed (B) synchronous speed
(C) shaft torque (D) core-loss component

YEAR 2012 TWO MARKS

MCQ 1.4.7 A 220 V, 15 kW, 100 rpm shunt motor with armature resistance of 0.25 Ω, has a rated line current of 68 A and a rated field current of 2.2 A. The change in field flux required to obtain a speed of 1600 rpm while drawing a line current of 52.8 A and a field current of 1.8 A is
(A) 18.18% increase (B) 18.18% decrease
(C) 36.36% increase (D) 36.36% decrease

MCQ 1.4.8 The locked rotor current in a 3-phase, star connected 15 kW, 4 pole, 230 V, 50 Hz induction motor at rated conditions is 50 A. Neglecting losses and magnetizing current, the approximate locked rotor line current drawn when the motor is connected to a 236 V, 57 Hz supply is
(A) 58.5 A (B) 45.0 A
(C) 42.7 A (D) 55.6 A

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MCQ 1.4.9 A single phase 10 kVA, 50 Hz transformer with 1 kV primary winding draws 0.5 A and 55 W, at rated voltage and frequency, on no load. A second transformer has a core with all its linear dimensions $\sqrt{2}$ times the corresponding dimensions of the first transformer. The core material and lamination thickness are the same in both transformer. The primary winding of both the transformers have the save number of turns. If a rate voltage of 2 kV at 50 Hz is applied to the primary of the second transformer, then the no load current and power, respectively, are
(A) 0.7 A, 77.8 A (B) 0.7 A, 155.6 W
(C) 1 A, 110 W (D) 1 A, 220 W

YEAR 2011 ONE MARK

MCQ 1.4.10 A 4 point starter is used to start and control the speed of a
(A) dc shunt motor with armature resistance control
(B) dc shunt motor with field weakening control
(C) dc series motor
(D) dc compound motor

MCQ 1.4.11 A three phase, salient pole synchronous motor is connected to an infinite bus. It is operated at no load a normal excitation. The field excitation of the motor is first reduced to zero and then increased in reverse direction gradually. Then the armature current.
(A) Increases continuously
(B) First increases and then decreases steeply

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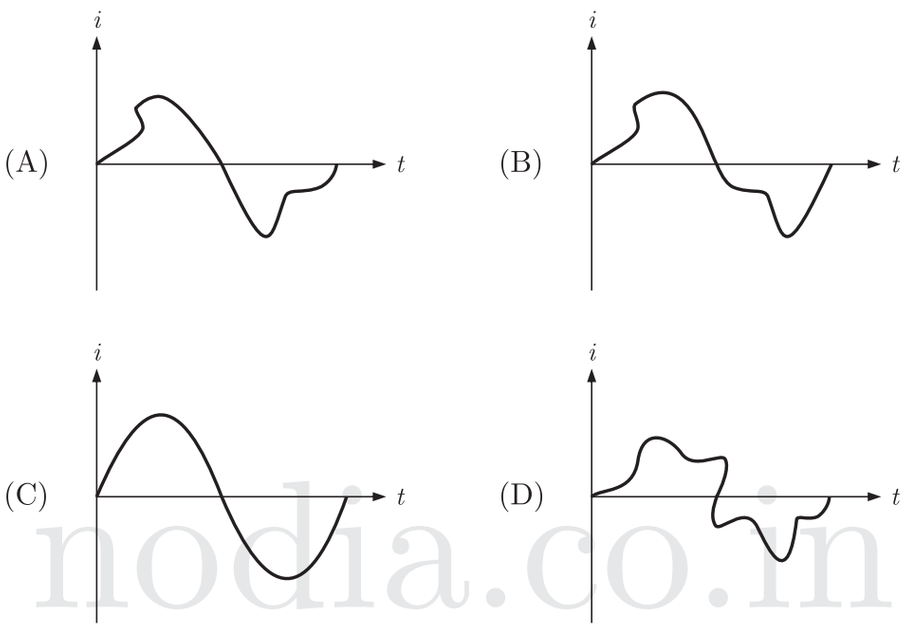
(C) First decreases and then increases steeply

(D) Remains constant

MCQ 1.4.12 A single phase air core transformer, fed from a rated sinusoidal supply, is operating at no load. The steady state magnetizing current drawn by the transformer from the supply will have the waveform



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YEAR 2011 TWO MARKS

MCQ 1.4.13 A 220 V, DC shunt motor is operating at a speed of 1440 rpm. The armature resistance is 1.0 Ω and armature current is 10 A. of the excitation of the machine is reduced by 10%, the extra resistance to be put in the armature circuit to maintain the same speed and torque will be

(A) 1.79 Ω (B) 2.1 Ω

(C) 18.9 Ω (D) 3.1 Ω

MCQ 1.4.14 A three-phase 440 V, 6 pole, 50 Hz, squirrel cage induction motor is running at a slip of 5%. The speed of stator magnetic field to rotor magnetic field and speed of rotor with respect of stator magnetic field are

(A) zero, −5 rpm (B) zero, 955 rpm

(C) 1000 rpm, −5 rpm (D) 1000 rpm, 955 rpm

YEAR 2010 ONE MARK

MCQ 1.4.15 A Single-phase transformer has a turns ratio 1:2, and is connected to a purely resistive load as shown in the figure. The magnetizing current drawn is 1 A, and the secondary current is 1 A. If core losses and leakage reactances are neglected, the primary current is

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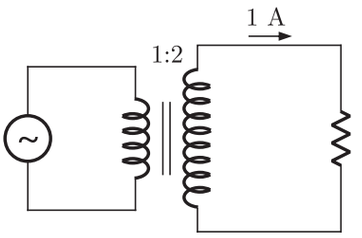


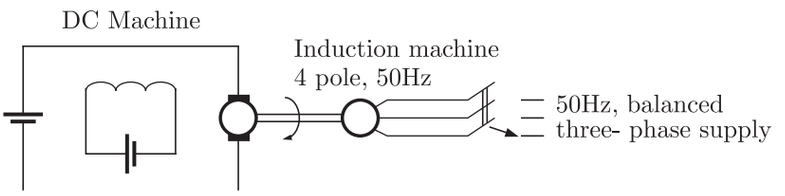
(A) 1.41 A
(B) 2 A
(C) 2.24 A
(D) 3 A

MCQ 1.4.16 A balanced three-phase voltage is applied to a star-connected induction motor, the phase to neutral voltage being V. The stator resistance, rotor resistance referred to the stator, stator leakage reactance, rotor leakage reactance referred to the stator, and the magnetizing reactance are denoted by r_s, r_r, X_s, X_r and X_m, respectively. The magnitude of the starting current of the motor is given by

(A) $\dfrac{V_s}{\sqrt{(r_s+r_r)^2+(X_s+X_r)^2}}$
(B) $\dfrac{V_s}{\sqrt{r_s^2+(X_s+X_m)^2}}$
(C) $\dfrac{V_s}{\sqrt{(r_s+r_r)^2+(X_m+X_r)^2}}$
(D) $\dfrac{V_s}{\sqrt{r_s^2+(X_m+X_r)^2}}$

YEAR 2010 TWO MARKS

MCQ 1.4.17 A separately excited dc machine is coupled to a 50 Hz, three-phase, 4-pole induction machine as shown in figure. The dc machine is energized first and the machines rotate at 1600 rpm. Subsequently the induction machine is also connected to a 50 Hz, three-phase source, the phase sequence being consistent with the direction of rotation. In steady state



(A) both machines act as generator
(B) the dc machine acts as a generator, and the induction machine acts as a motor
(C) the dc machine acts as a motor, and the induction machine acts as a generator
(D) both machines act as motors

MCQ 1.4.18 A balanced star-connected and purely resistive load is connected at the secondary of a star-delta transformer as shown in figure. The line-to line voltage rating of the transformer is 110 V/200 V.
Neglecting the non-idealities of the transformer, the impedance Z of the equivalent star-connected load, referred to the primary side of the transformer, is

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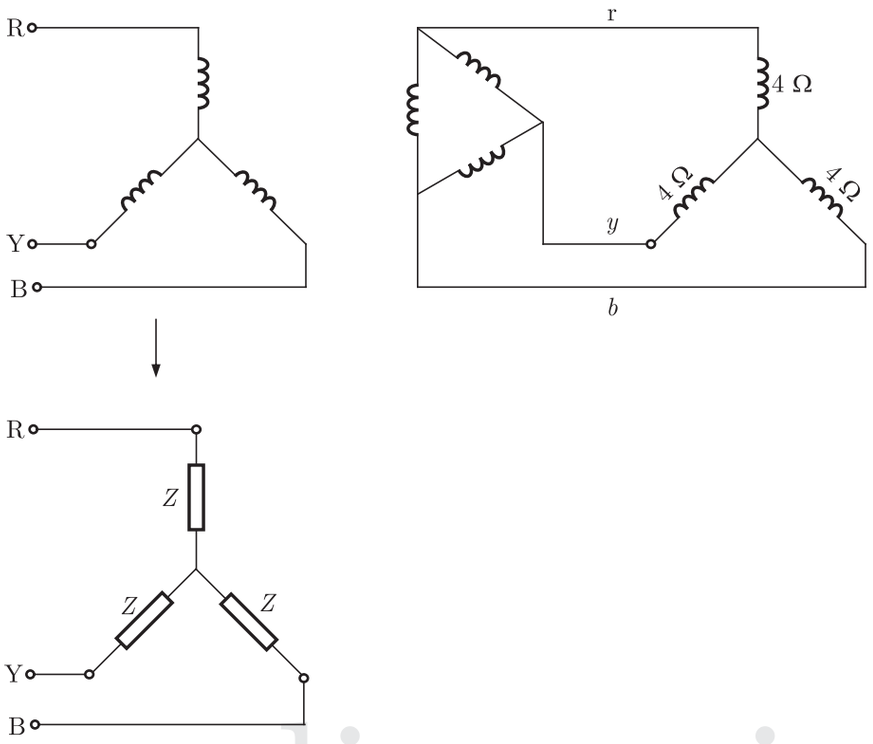

(A) $(3+j0)\,\Omega$ (B) $(0.866-j0.5)\,\Omega$

(C) $(0.866+j0.5)\,\Omega$ (D) $(1+j0)\,\Omega$

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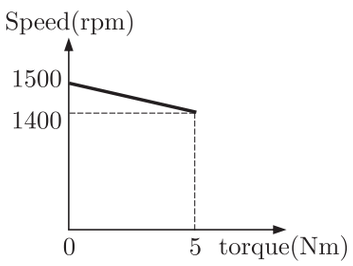
Common Data for Questions 19 and 20

A separately excited DC motor runs at 1500 rpm under no-load with 200 V applied to the armature. The field voltage is maintained at its rated value. The speed of the motor, when it delivers a torque of 5 Nm, is 1400 rpm as shown in figure. The rotational losses and armature reaction are neglected.



MCQ 1.4.19 The armature resistance of the motor is

(A) 2 Ω (B) 3.4 Ω

(C) 4.4 Ω (D) 7.7 Ω

MCQ 1.4.20 For the motor to deliver a torque of 2.5 Nm at 1400 rpm, the armature voltage to be applied is

(A) 125.5 V (B) 193.3 V

(C) 200 V (D) 241.7 V

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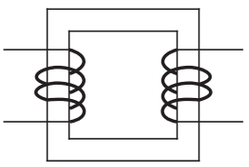
MCQ 1.4.21 A field excitation of 20 A in a certain alternator results in an armature current of 400 A in short circuit and a terminal voltage of 2000 V on open circuit. The magnitude of the internal voltage drop within the machine at a load current of 200 A is

(A) 1 V (B) 10 V

(C) 100 V (D) 1000 V

MCQ 1.4.22 The single phase, 50 Hz iron core transformer in the circuit has both the vertical arms of cross sectional area 20 cm^2 and both the horizontal arms of cross sectional area 10 cm^2. If the two windings shown were wound instead on opposite horizontal arms, the mutual inductance will



(A) double (B) remain same

(C) be halved (D) become one quarter

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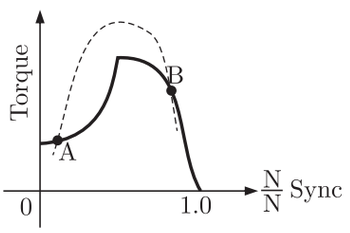
MCQ 1.4.23 A 3-phase squirrel cage induction motor supplied from a balanced 3-phase source drives a mechanical load. The torque-speed characteristics of the motor (solid curve) and of the load (dotted curve) are shown. Of the two equilibrium points A and B, which of the following options correctly describes the stability of A and B ?



(A) A is stable, B is unstable (B) A is unstable, B is stable

(C) Both are stable (D) Both are unstable

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MCQ 1.4.24 A 200 V, 50 Hz, single-phase induction motor has the following connection diagram and winding orientations as shown. MM' is the axis of the main stator winding(M_1M_2) and AA' is that of the auxiliary winding(A_1A_2). Directions of the winding axis indicate direction of flux when currents in the windings are in the directions shown. Parameters of each winding are indicated. When switch S is closed the motor

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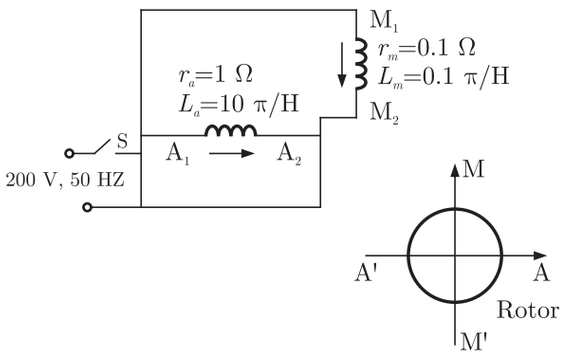


(A) rotates clockwise

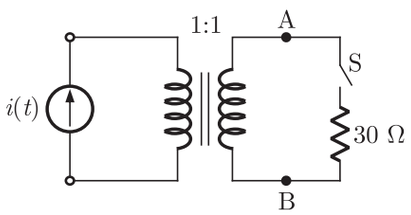
(B) rotates anti-clockwise

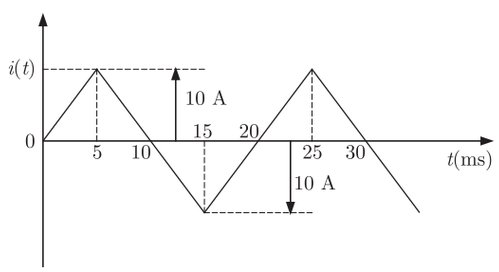
(C) does not rotate

(D) rotates momentarily and comes to a halt

Common Data for Questions 25 and 26 :

The circuit diagram shows a two-winding, lossless transformer with no leakage flux, excited from a current source, $i(t)$, whose waveform is also shown. The transformer has a magnetizing inductance of $400/\pi$ mH.





MCQ 1.4.25 The peak voltage across A and B, with S open is

(A) $\frac{400}{\pi}$ V (B) 800 V

(C) $\frac{4000}{\pi}$ V (D) $\frac{800}{\pi}$ V

MCQ 1.4.26 If the wave form of $i(t)$ is changed to $i(t) = 10\sin(100\pi t)$ A, the peak voltage across A and B with S closed is

(A) 400 V (B) 240 V

(C) 320 V (D) 160 V

MCQ 1.4.27 Figure shows the extended view of a 2-pole dc machine with 10 armature conductors. Normal brush positions are shown by A and B, placed at the interpolar axis. If the brushes are now shifted, in the direction of rotation, to A' and B' as shown,

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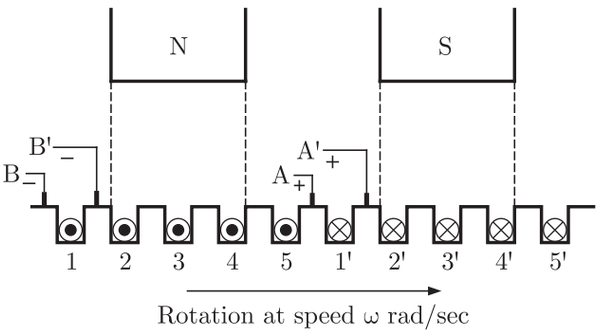
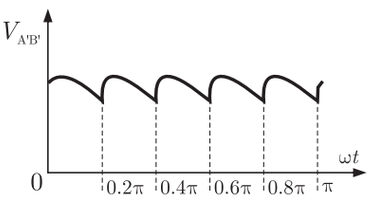
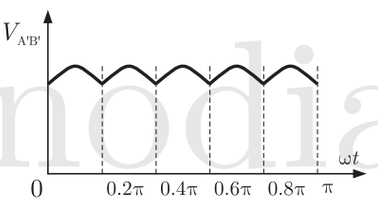
the voltage waveform $V_{A'B'}$ will resemble



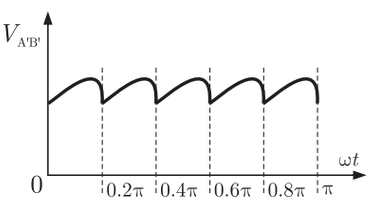
(A)



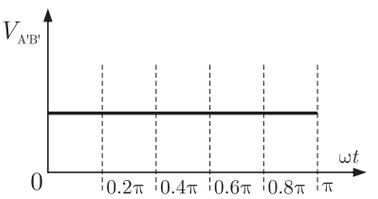
(B)



(C)



(D)



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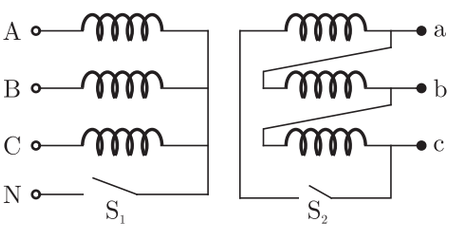
Common Data for Questions 28 and 29:



The star-delta transformer shown above is excited on the star side with balanced, 4-wire, 3-phase, sinusoidal voltage supply of rated magnitude. The transformer is under no load condition

MCQ 1.4.28 With both S1 and S2 open, the core flux waveform will be

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(A) a sinusoid at fundamental frequency

(B) flat-topped with third harmonic

(C) peaky with third-harmonic

(D) none of these

MCQ 1.4.29 With S2 closed and S1 open, the current waveform in the delta winding will be

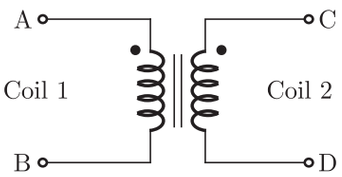
(A) a sinusoid at fundamental frequency

(B) flat-topped with third harmonic

(C) only third-harmonic

(D) none of these

Statement for Linked Answer Questions 30 and 31 :



The figure above shows coils-1 and 2, with dot markings as shown, having 4000 and 6000 turns respectively. Both the coils have a rated current of 25 A. Coil-1 is excited with single phase, 400 V, 50 Hz supply.

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MCQ 1.4.30 The coils are to be connected to obtain a single-phase, $\frac{400}{1000}$ V, auto-transformer to drive a load of 10 kVA. Which of the options given should be exercised to realize the required auto-transformer ?

(A) Connect A and D; Common B

(B) Connect B and D; Common C

(C) Connect A and C; Common B

(D) Connect A and C; Common D

MCQ 1.4.31 In the autotransformer obtained in Question 16, the current in each coil is

(A) Coil-1 is 25 A and Coil-2 is 10 A

(B) Coil-1 is 10 A and Coil-2 is 25 A

(C) Coil-1 is 10 A and Coil-2 is 15 A

(D) Coil-1 is 15 A and Coil-2 is 10 A

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MCQ 1.4.32 Distributed winding and short chording employed in AC machines will result in

(A) increase in emf and reduction in harmonics

(B) reduction in emf and increase in harmonics

(C) increase in both emf and harmonics

(D) reduction in both emf and harmonics

MCQ 1.4.33 Three single-phase transformer are connected to form a 3-phase transformer bank. The transformers are connected in the following manner :

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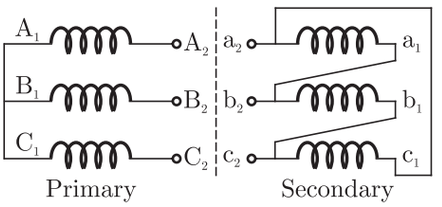

The transformer connecting will be represented by

(A) Y d0 (B) Y d1

(C) Y d6 (D) Y d11

MCQ 1.4.34 In a stepper motor, the detent torque means

(A) minimum of the static torque with the phase winding excited

(B) maximum of the static torque with the phase winding excited

(C) minimum of the static torque with the phase winding unexcited

(D) maximum of the static torque with the phase winding unexcited

MCQ 1.4.35 It is desired to measure parameters of 230 V/115 V, 2 kVA, single-phase transformer. The following wattmeters are available in a laboratory:

W_1 : 250 V, 10 A, Low Power Factor

W_2 : 250 V, 5 A, Low Power Factor

W_3 : 150 V, 10 A, High Power Factor

W_4 : 150 V, 5 A, High Power Factor

The Wattmeters used in open circuit test and short circuit test of the transformer will respectively be

(A) W_1 and W_2 (B) W_2 and W_4

(C) W_1 and W_4 (D) W_2 and W_3

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MCQ 1.4.36 A 230 V, 50 Hz, 4-pole, single-phase induction motor is rotating in the clockwise (forward) direction at a speed of 1425 rpm. If the rotor resistance at standstill is 7.8 Ω, then the effective rotor resistance in the backward branch of the equivalent circuit will be

(A) 2 Ω (B) 4 Ω

(C) 78 Ω (D) 156 Ω

MCQ 1.4.37 A 400 V, 50 Hz 30 hp, three-phase induction motor is drawing 50 A current at 0.8 power factor lagging. The stator and rotor copper losses are 1.5 kW and 900 W respectively. The friction and windage losses are 1050 W and the core losses are 1200 W. The air-gap power of the motor will be

(A) 23.06 kW (B) 24.11 kW

(C) 25.01 kW (D) 26.21 kW

MCQ 1.4.38 The core of a two-winding transformer is subjected to a magnetic flux variation as indicated in the figure.

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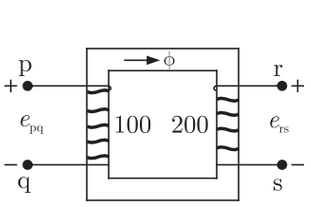
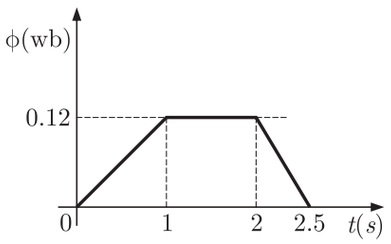
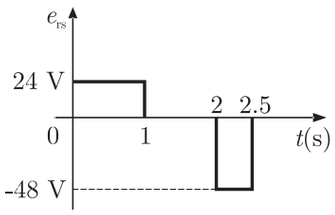


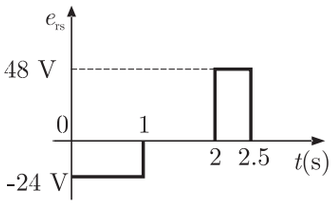


The induced emf (e_{rs}) in the secondary winding as a function of time will be of the form

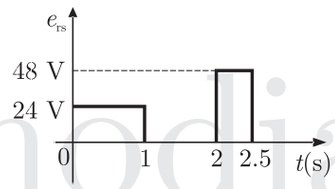
(A)



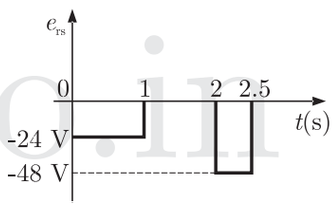
(B)



(C)



(D)



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MCQ 1.4.39 A 400 V, 50 Hz, 4-pole, 1400 rpm, star connected squirrel cage induction motor has the following parameters referred to the stator:

$R_r' = 1.0\,\Omega, X_s = X_r' = 1.5\,\Omega$

Neglect stator resistance and core and rotational losses of the motor. The motor is controlled from a 3-phase voltage source inverter with constant V/f control. The stator line-to-line voltage(rms) and frequency to obtain the maximum torque at starting will be :

(A) 20.6 V, 2.7 Hz

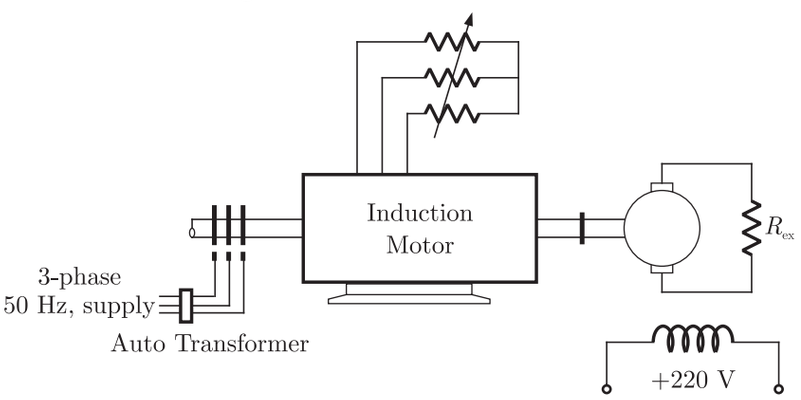
(B) 133.3 V, 16.7 Hz

(C) 266.6 V, 33.3 Hz

(D) 323.3 V, 40.3 Hz

Common Data for Questions 40 and 41.

A 3-phase, 440 V, 50 Hz, 4-pole slip ring induction motor is feed from the rotor side through an auto-transformer and the stator is connected to a variable resistance as shown in the figure.



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The motor is coupled to a 220 V, separately excited d.c generator feeding power to fixed resistance of 10 Ω. Two-wattmeter method is used to measure the input power to induction motor. The variable resistance is adjusted such the motor runs at 1410 rpm and the following readings were recorded $W_1 = 1800$ W, $W_2 = -200$ W.

MCQ 1.4.40 The speed of rotation of stator magnetic field with respect to rotor structure will be

(A) 90 rpm in the direction of rotation

(B) 90 rpm in the opposite direction of rotation

(C) 1500 rpm in the direction of rotation

(D) 1500 rpm in the opposite direction of rotation

MCQ 1.4.41 Neglecting all losses of both the machines, the dc generator power output and the current through resistance (R_{ex}) will respectively be

(A) 96 W, 3.10 A

(B) 120 W, 3.46 A

(C) 1504 W, 12.26 A

(D) 1880 W, 13.71 A

Statement for Linked Answer Question 42 and 43.

A 240 V, dc shunt motor draws 15 A while supplying the rated load at a speed of 80 rad/s. The armature resistance is 0.5 Ω and the field winding resistance is 80 Ω.

MCQ 1.4.42 The net voltage across the armature resistance at the time of plugging will be

(A) 6 V

(B) 234 V

(C) 240 V

(D) 474 V

MCQ 1.4.43 The external resistance to be added in the armature circuit to limit the armature current to 125% of its rated value is

(A) 31.1 Ω

(B) 31.9 Ω

(C) 15.1 Ω

(D) 15.9 Ω

Statement for Linked Answer Question 44 and 45.

A synchronous motor is connected to an infinite bus at 1.0 pu voltage and draws 0.6 pu current at unity power factor. Its synchronous reactance is 1.0 pu resistance is negligible.

MCQ 1.4.44 The excitation voltage (E) and load angle (δ) will respectively be

(A) 0.8 pu and 36.86c lag

(B) 0.8 pu and 36.86c lead

(C) 1.17 pu and 30.96c lead

(D) 1.17 pu and 30.96c lag

MCQ 1.4.45 Keeping the excitation voltage same, the load on the motor is increased such that the motor current increases by 20%. The operating power factor will become

(A) 0.995 lagging

(B) 0.995 leading

(C) 0.791 lagging

(D) 0.848 leading

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MCQ 1.4.46 In a transformer, zero voltage regulation at full load is

(A) not possible

(B) possible at unity power factor load

(C) possible at leading power factor load

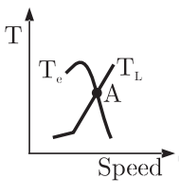
(D) possible at lagging power factor load

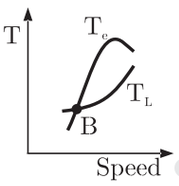
MCQ 1.4.47 The dc motor, which can provide zero speed regulation at full load without any controller is

(A) series (B) shunt

(C) cumulative compound (D) differential compound

MCQ 1.4.48 The electromagnetic torque T_e of a drive and its connected load torque T_L are as shown below. Out of the operating points A, B, C and D, the stable ones are

(A) 

(B) 

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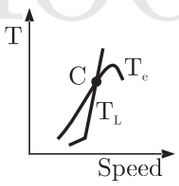
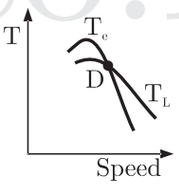
(C) 

(D) 

(A) A, C, D (B) B, C

(C) A, D (D) B, C, D

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MCQ 1.4.49 A three-phase synchronous motor connected to ac mains is running at full load and unity power factor. If its shaft load is reduced by half, with field current held constant, its new power factor will be

(A) unity

(B) leading

(C) lagging

(D) dependent on machine parameters

MCQ 1.4.50 A 100 kVA, 415 V(line), star-connected synchronous machine generates rated open circuit voltage of 415 V at a field current of 15 A. The short circuit armature current at a field current of 10 A is equal to the rated armature current. The per unit saturated synchronous reactance is

(A) 1.731 (B) 1.5

(C) 0.666 (D) 0.577

MCQ 1.4.51 A single-phase, 50 kVA, 250 V/500 V two winding transformer has an efficiency

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of 95% at full load, unity power factor. If it is re-configured as a 500 V/750 V auto-transformer, its efficiency at its new rated load at unity power factor will be

(A) 95.752% (B) 97.851%

(C) 98.276% (D) 99.241%

MCQ 1.4.52 A three-phase, three-stack, variable reluctance step motor has 20 poles on each rotor and stator stack. The step angle of this step motor is

(A) 3c (B) 6c

(C) 9c (D) 18c

MCQ 1.4.53 A three-phase squirrel cage induction motor has a starting torque of 150% and a maximum torque of 300% with respect to rated torque at rated voltage and rated frequency. Neglect the stator resistance and rotational losses. The value of slip for maximum torque is

(A) 13.48% (B) 16.42%

(C) 18.92% (D) 26.79%

Common Data for Question 54, 55 and 56:

A three phase squirrel cage induction motor has a starting current of seven times the full load current and full load slip of 5%

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MCQ 1.4.54 If an auto transformer is used for reduced voltage starting to provide 1.5 per unit starting torque, the auto transformer ratio(%) should be

(A) 57.77 % (B) 72.56 %

(C) 78.25 % (D) 81.33 %

MCQ 1.4.55 If a star-delta starter is used to start this induction motor, the per unit starting torque will be

(A) 0.607 (B) 0.816

(C) 1.225 (D) 1.616

MCQ 1.4.56 If a starting torque of 0.5 per unit is required then the per unit starting current should be

(A) 4.65 (B) 3.75

(C) 3.16 (D) 2.13

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MCQ 1.4.57 In transformers, which of the following statements is valid ?

(A) In an open circuit test, copper losses are obtained while in short circuit test, core losses are obtained

(B) In an open circuit test, current is drawn at high power factor

(C) In a short circuit test, current is drawn at zero power factor

(D) In an open circuit test, current is drawn at low power factor

MCQ 1.4.58 For a single phase capacitor start induction motor which of the following statements is valid ?

(A) The capacitor is used for power factor improvement

(B) The direction of rotation can be changed by reversing the main winding

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terminals

(C) The direction of rotation cannot be changed

(D) The direction of rotation can be changed by interchanging the supply terminals

MCQ 1.4.59 In a DC machine, which of the following statements is true ?

(A) Compensating winding is used for neutralizing armature reaction while interpole winding is used for producing residual flux

(B) Compensating winding is used for neutralizing armature reaction while interpole winding is used for improving commutation

(C) Compensating winding is used for improving commutation while interpole winding is used for neutralizing armature reaction

(D) Compensation winding is used for improving commutation while interpole winding is used for producing residual flux

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MCQ 1.4.60 A 220 V DC machine supplies 20 A at 200 V as a generator. The armature resistance is 0.2 ohm. If the machine is now operated as a motor at same terminal voltage and current but with the flux increased by 10%, the ratio of motor speed to generator speed is

(A) 0.87 (B) 0.95

(C) 0.96 (D) 1.06

MCQ 1.4.61 A synchronous generator is feeding a zero power factor (lagging) load at rated current. The armature reaction is

(A) magnetizing (B) demagnetizing

(C) cross-magnetizing (D) ineffective

MCQ 1.4.62 Two transformers are to be operated in parallel such that they share load in proportion to their kVA ratings. The rating of the first transformer is 500 kVA ratings. The rating of the first transformer is 500 kVA and its pu leakage impedance is 0.05 pu. If the rating of second transformer is 250 kVA, its pu leakage impedance is

(A) 0.20 (B) 0.10

(C) 0.05 (D) 0.025

MCQ 1.4.63 The speed of a 4-pole induction motor is controlled by varying the supply frequency while maintaining the ratio of supply voltage to supply frequency (V/f) constant. At rated frequency of 50 Hz and rated voltage of 400 V its speed is 1440 rpm. Find the speed at 30 Hz, if the load torque is constant

(A) 882 rpm (B) 864 rpm

(C) 840 rpm (D) 828 rpm

MCQ 1.4.64 A 3-phase, 4-pole, 400 V 50 Hz , star connected induction motor has following circuit parameters

$$r_1 = 1.0\,\Omega, r'_2 = 0.5\,\Omega, X_1 = X'_2 = 1.2\,\Omega, X_m = 35\,\Omega$$

The starting torque when the motor is started direct-on-line is (use approximate equivalent circuit model)

(A) 63.6 Nm (B) 74.3 Nm

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(C) 190.8 Nm (D) 222.9 Nm

MCQ 1.4.65 A 3-phase, 10 kW, 400 V, 4-pole, 50Hz, star connected induction motor draws 20 A on full load. Its no load and blocked rotor test data are given below.
No Load Test: 400 V 6 A 1002 W
Blocked Rotor Test : 90 V 15 A 762 W
Neglecting copper loss in no load test and core loss in blocked rotor test, estimate motor's full load efficiency
(A) 76% (B) 81%
(C) 82.4% (D) 85%

MCQ 1.4.66 A 3-phase, 400 V, 5 kW, star connected synchronous motor having an internal reactance of 10 Ω is operating at 50% load, unity p.f. Now, the excitation is increased by 1%. What will be the new load in percent, if the power factor is to be kept same ? Neglect all losses and consider linear magnetic circuit.
(A) 67.9% (B) 56.9%
(C) 51% (D) 50%

Data for Q. 67 to Q 69 are given below.

A 4-pole, 50 Hz, synchronous generator has 48 slots in which a double layer winding is housed. Each coil has 10 turns and is short pitched by an angle to 36c electrical. The fundamental flux per pole is 0.025 Wb

MCQ 1.4.67 The line-to-line induced emf(in volts), for a three phase star connection is approximately
(A) 808 (B) 888
(C) 1400 (D) 1538

MCQ 1.4.68 The line-to-line induced emf(in volts), for a three phase connection is approximately
(A) 1143 (B) 1332
(C) 1617 (D) 1791

MCQ 1.4.69 The fifth harmonic component of phase emf(in volts), for a three phase star connection is
(A) 0 (B) 269
(C) 281 (D) 808

Statement for Linked Answer Questions 70 and 71.

A 300 kVA transformer has 95% efficiency at full load 0.8 p.f. lagging and 96% efficiency at half load, unity p.f.

MCQ 1.4.70 The iron loss (P_i) and copper loss (P_c) in kW, under full load operation are
(A) $P_c = 4.12, P_i = 8.51$ (B) $P_c = 6.59, P_i = 9.21$
(C) $P_c = 8.51, P_i = 4.12$ (D) $P_c = 12.72, P_i = 3.07$

MCQ 1.4.71 What is the maximum efficiency (in %) at unity p.f. load ?
(A) 95.1 (B) 96.2
(C) 96.4 (D) 98.1

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MCQ 1.4.72 The equivalent circuit of a transformer has leakage reactances X_1, X'_2 and magnetizing reactance X_M. Their magnitudes satisfy

(A) $X_1 >> X'_2 >> X_M$ (B) $X_1 << X'_2 << X_M$

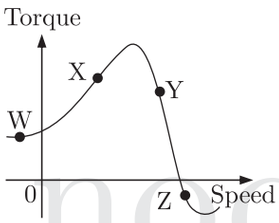
(C) $X_1 \ . \ X'_2 >> X_M$ (D) $X_1 \ . \ X'_2 << X_M$

MCQ 1.4.73 Which three-phase connection can be used in a transformer to introduce a phase difference of 30c between its output and corresponding input line voltages

(A) Star-Star (B) Star-Delta

(C) Delta-Delta (D) Delta-Zigzag

MCQ 1.4.74 On the torque/speed curve of the induction motor shown in the figure four points of operation are marked as W, X, Y and Z. Which one of them represents the operation at a slip greater than 1 ?



(A) W (B) X

(C) Y (D) Z

MCQ 1.4.75 For an induction motor, operation at a slip s, the ration of gross power output to air gap power is equal to

(A) $(1-s)^2$ (B) $(1-s)$

(C) $\sqrt{(1-s)}$ (D) $(1-\sqrt{s})$

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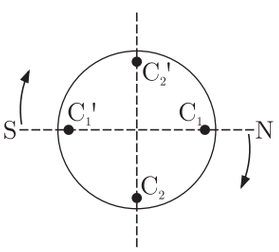
MCQ 1.4.76 Two magnetic poles revolve around a stationary armature carrying two coil $(c_1 - c_1|, c_2 - c_2|)$ as shown in the figure. Consider the instant when the poles are in a position as shown. Identify the correct statement regarding the polarity of the induced emf at this instant in coil sides c_1 and c_2.



(A) **9** in c_1, no emf in c_2 (B) **7** in c_1, no emf in c_2

(C) **9** in c_2, no emf in c_1 (D) **7** in c_2, no emf in c_1

MCQ 1.4.77 A 50 kW dc shunt is loaded to draw rated armature current at any given speed. When driven

(i) at half the rated speed by armature voltage control and

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(ii) at 1.5 times the rated speed by field control, the respective output powers delivered by the motor are approximately.

(A) 25 kW in (i) and 75 kW in (ii)

(B) 25 kW in (i) and 50 kW in (ii)

(C) 50 kW in (i) and 75 kW in (ii)

(D) 50 kW in (i) and 50 kW in (ii)

MCQ 1.4.78 In relation to the synchronous machines, which on of the following statements is false ?

(A) In salient pole machines, the direct-axis synchronous reactance is greater than the quadrature-axis synchronous reactance.

(B) The damper bars help the synchronous motor self start.

(C) Short circuit ratio is the ratio of the field current required to produces the rated voltage on open circuit to the rated armature current.

(D) The V-cure of a synchronous motor represents the variation in the armature current with field excitation, at a given output power.

MCQ 1.4.79 In relation to DC machines, match the following and choose the correct combination

	List-I Performance Variables	List-II Proportional to
P.	Armature emf (E)	1. Flux(ϕ), speed (ω) and armature current (I_a)
Q.	Developed torque (T)	2. ϕ and ω only
R	Developed power (P)	3. ϕ and I_a only
		4. I_a and ω only
		5. I_a only

Codes:

	P	Q	R
(A)	3	3	1
(B)	2	5	4
(C)	3	5	4
(D)	2	3	1

MCQ 1.4.80 Under no load condition, if the applied voltage to an induction motor is reduced from the rated voltage to half the rated value,

(A) the speed decreases and the stator current increases

(B) both the speed and the stator current decreases

(C) the speed and the stator current remain practically constant

(D) there is negligible change in the speed but the stator current decreases

MCQ 1.4.81 A three-phase cage induction motor is started by direct-on-line (DOL) switching at the rated voltage. If the starting current drawn is 6 times the full load current, and the full load slip is 4%, then ratio of the starting developed torque to the full load torque is approximately equal to

(A) 0.24 (B) 1.44

(C) 2.40 (D) 6.00

MCQ 1.4.82 In a single phase induction motor driving a fan load, the reason for having a high

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resistance rotor is to achieve

(A) low starting torque (B) quick acceleration

(C) high efficiency (D) reduced size

MCQ 1.4.83 Determine the correctness or otherwise of the following assertion[A] and the reason[R]

Assertion [A] : Under V/f control of induction motor, the maximum value of the developed torque remains constant over a wide range of speed in the sub-synchronous region.

Reason [R] : The magnetic flux is maintained almost constant at the rated value by keeping the ration V/f constant over the considered speed range.

(A) Both [A] and [R] are true and [R] is the correct reason for [A]

(B) Both [A] and [R] are true and but [R] is not the correct reason for [A]

(C) Both [A] and [R] are false

(D) [A] is true but [R] is false

Statement for Linked Answer Questions 84 and 85.

A 1000 kVA, 6.6 kV, 3-phase star connected cylindrical pole synchronous generator has a synchronous reactance of 20 Ω. Neglect the armature resistance and consider operation at full load and unity power factor.

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MCQ 1.4.84 The induced emf(line-to-line) is close to

(A) 5.5 kV (B) 7.2 kV

(C) 9.6 kV (D) 12.5 kV

MCQ 1.4.85 The power(or torque) angle is close to

(A) 13.9c (B) 18.3c

(C) 24.6c (D) 33.0c

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MCQ 1.4.86 A 500 kVA, 3-phase transformer has iron losses of 300 W and full load copper losses of 600 W. The percentage load at which the transformer is expected to have maximum efficiency is

(A) 50.0% (B) 70.7%

(C) 141.4% (D) 200.0%

MCQ 1.4.87 For a given stepper motor, the following torque has the highest numerical value

(A) Detent torque (B) Pull-in torque

(C) Pull-out torque (D) Holding torque

MCQ 1.4.88 The following motor definitely has a permanent magnet rotor

(A) DC commutator motor (B) Brushless dc motor

(C) Stepper motor (D) Reluctance motor

MCQ 1.4.89 The type of single-phase induction motor having the highest power factor at full load is

(A) shaded pole type (B) split-phase type

(C) capacitor-start type (D) capacitor-run type

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MCQ 1.4.90 The direction of rotation of a 3-phase induction motor is clockwise when it is supplied with 3-phase sinusoidal voltage having phase sequence A-B-C. For counter clockwise rotation of the motor, the phase sequence of the power supply should be

(A) B-C-A (B) C-A-B

(C) A-C-B (D) B-C-A or C-A-B

MCQ 1.4.91 For a linear electromagnetic circuit, the following statement is true

(A) Field energy is equal to the co-energy

(B) Field energy is greater than the co-energy

(C) Field energy is lesser than the co-energy

(D) Co-energy is zero

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MCQ 1.4.92 The synchronous speed for the seventh space harmonic mmf wave of a 3-phase, 8-pole, 50 Hz induction machine is

(A) 107.14 rpm in forward direction

(B) 107.14 rpm in reverse direction

(C) 5250 rpm in forward direction

(D) 5250 rpm in reverse direction

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MCQ 1.4.93 A rotating electrical machine its self-inductances of both the stator and the rotor windings, independent of the rotor position will be definitely not develop

(A) starting torque (B) synchronizing torque

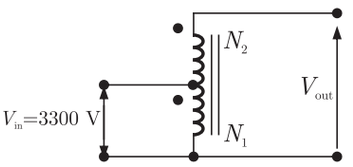
(C) hysteresis torque (D) reluctance torque

MCQ 1.4.94 The armature resistance of a permanent magnet dc motor is 0.8 Ω. At no load, the motor draws 1.5 A from a supply voltage of 25 V and runs at 1500 rpm. The efficiency of the motor while it is operating on load at 1500 rpm drawing a current of 3.5 A from the same source will be

(A) 48.0% (B) 57.1%

(C) 59.2% (D) 88.8%

MCQ 1.4.95 A 50 kVA, 3300/230 V single-phase transformer is connected as an auto-transformer shown in figure. The nominal rating of the auto- transformer will be



(A) 50.0 kVA (B) 53.5 kVA

(C) 717.4 kVA (D) 767.4 kVA

MCQ 1.4.96 The resistance and reactance of a 100 kVA, 11000/400 V, **3**− Y distribution transformer are 0.02 and 0.07 pu respectively. The phase impedance of the transformer referred to the primary is

(A) $(0.02 + j0.07)\,\Omega$ (B) $(0.55 + j1.925)\,\Omega$

(C) $(15.125 + j52.94)\,\Omega$ (D) $(72.6 + j254.1)\,\Omega$

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MCQ 1.4.97 A single-phase, 230 V, 50 Hz 4-pole, capacitor-start induction motor had the following stand-still impedances
Main winding $Z_m = 6.0 + j4.0\,\Omega$
Auxiliary winding $Z_a = 8.0 + j6.0\,\Omega$
The value of the starting capacitor required to produce 90c phase difference between the currents in the main and auxiliary windings will be
(A) 176.84 μF (B) 187.24 μF
(C) 265.26 μF (D) 280.86 μF

MCQ 1.4.98 Two 3-phase, Y-connected alternators are to be paralleled to a set of common busbars. The armature has a per phase synchronous reactance of 1.7 Ω and negligible armature resistance. The line voltage of the first machine is adjusted to 3300 V and that of the second machine is adjusted to 3200 V. The machine voltages are in phase at the instant they are paralleled. Under this condition, the synchronizing current per phase will be
(A) 16.98 A (B) 29.41 A
(C) 33.96 A (D) 58.82 A

MCQ 1.4.99 A 400 V, 15 kW, 4-pole, 50Hz, Y-connected induction motor has full load slip of 4%. The output torque of the machine at full load is
(A) 1.66 Nm (B) 95.50 Nm
(C) 99.47 Nm (D) 624.73 Nm

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MCQ 1.4.100 For a 1.8c, 2-phase bipolar stepper motor, the stepping rate is 100 steps/second. The rotational speed of the motor in rpm is
(A) 15 (B) 30
(C) 60 (D) 90

MCQ 1.4.101 A 8-pole, DC generator has a simplex wave-wound armature containing 32 coils of 6 turns each. Its flux per pole is 0.06 Wb. The machine is running at 250 rpm. The induced armature voltage is
(A) 96 V (B) 192 V
(C) 384 V (D) 768 V

MCQ 1.4.102 A 400 V, 50 kVA, 0.8 p.f. leading **3**-connected, 50 Hz synchronous machine has a synchronous reactance of 2 Ω and negligible armature resistance. The friction and windage losses are 2 kW and the core loss is 0.8 kW. The shaft is supplying 9 kW load at a power factor of 0.8 leading. The line current drawn is
(A) 12.29 A (B) 16.24 A
(C) 21.29 A (D) 36.88 A

MCQ 1.4.103 A 500 MW, 3-phase, Y-connected synchronous generator has a rated voltage of 21.5 kV at 0.85 p.f. The line current when operating at full load rated conditions will be
(A) 13.43 kA (B) 15.79 kA
(C) 23.25 kA (D) 27.36 kA

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MCQ 1.4.104 A simple phase transformer has a maximum efficiency of 90% at full load and

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unity power factor. Efficiency at half load at the same power factor is

(A) 86.7% (B) 88.26%

(C) 88.9% (D) 87.8%

MCQ 1.4.105 Group-I lists different applications and Group-II lists the motors for these applications. Match the application with the most suitable motor and choose the right combination among the choices given thereafter

	Group-I		Group-II
P.	Food mixer	1.	Permanent magnet dc motor
Q	Cassette tape recorder	2.	Single-phase induction motor
R.	Domestic water pump	3.	Universal motor
S.	Escalator	4.	Three-phase induction motor
		5.	DC series motor
		6.	Stepper motor

Codes:

	P	Q	R	S
(A)	3	6	4	5
(B)	1	3	2	4
(C)	3	1	2	4
(D)	3	2	1	4

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MCQ 1.4.106 A stand alone engine driven synchronous generator is feeding a partly inductive load. A capacitor is now connected across the load to completely nullify the inductive current. For this operating condition.

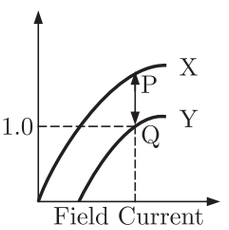
(A) the field current and fuel input have to be reduced

(B) the field current and fuel input have to be increased

(C) the field current has to be increased and fuel input left unaltered

(D) the field current has to be reduced and fuel input left unaltered

MCQ 1.4.107 Curves X and Y in figure denote open circuit and full-load zero power factor(zpf) characteristics of a synchronous generator. Q is a point on the zpf characteristics at 1.0 p.u. voltage. The vertical distance PQ in figure gives the voltage drop across



(A) Synchronous reactance (B) Magnetizing reactance

(C) Potier reactance (D) Leakage reactance

MCQ 1.4.108 No-load test on a 3-phase induction motor was conducted at different supply voltage and a plot of input power versus voltage was drawn. This curve was extrapolated to intersect the y-axis. The intersection point yields

(A) Core loss (B) Stator copper loss

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(C) Stray load loss (D) Friction and windage loss

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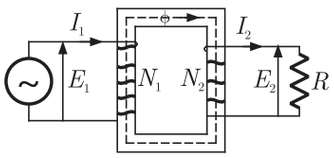
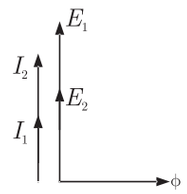
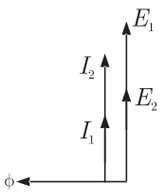
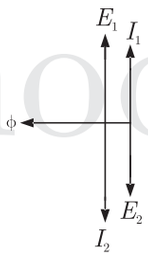
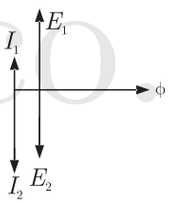
MCQ 1.4.109 Figure shows an ideal single-phase transformer. The primary and secondary coils are wound on the core as shown. Turns ratio $N_1/N_2 = 2$.The correct phasors of voltages E_1, E_2, currents I_1, I_2 and core flux Φ are as shown in



(A)


(B)


(C)


(D)


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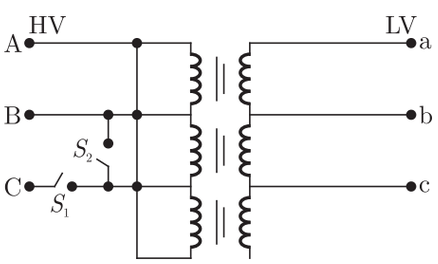
MCQ 1.4.110 To conduct load test on a dc shunt motor, it is coupled to a generator which is identical to the motor. The field of the generator is also connected to the same supply source as the motor. The armature of generator is connected to a load resistance. The armature resistance is 0.02 p.u. Armature reaction and mechanical losses can be neglected. With rated voltage across the motor, the load resistance across the generator is adjusted to obtain rated armature current in both motor and generator. The p.u value of this load resistance is

(A) 1.0 (B) 0.98

(C) 0.96 (D) 0.94

MCQ 1.4.111 Figure shows a $\mathbf{3}-Y$ connected, 3-phase distribution transformer used to step down the voltage from 11000 V to 415 V line-to-line. It has two switches S_1 and S_2. Under normal conditions S_1 is closed and S_2 is open. Under certain special conditions S_1 is open and S_2 is closed. In such a case the magnitude of the voltage across the LV terminals a and c is



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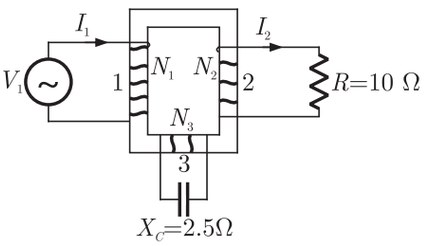
(A) 240 V (B) 480 V
(C) 415 V (D) 0 V

MCQ 1.4.112 Figure shows an ideal three-winding transformer. The three windings 1, 2, 3 of the transformer are wound on the same core as shown. The turns ratio $N_1 : N_2 : N_3$ is 4:2:1. A resistor of 10 Ω is connected across winding-2. A capacitor of reactance 2.5 Ω is connected across winding-3. Winding-1 is connected across a 400 V, ac supply. If the supply voltage phasor $V_1 = 400 \angle 0°$, the supply current phasor I_1 is given by



(A) $(-10 + j10)$ A (B) $(-10 - j10)$ A
(C) $(10 + j10)$ A (D) $(10 - j10)$ A

MCQ 1.4.113 Following are some of the properties of rotating electrical machines
P. Stator winding current is dc, rotor winding current is ac.
Q. Stator winding current is ac, rotor winding current is dc.
R. Stator winding current is ac, rotor winding current is ac.
S. Stator has salient poles and rotor has commutator.
T. Rotor has salient poles and sliprings and stator is cylindrical.
U. Both stator and rotor have poly-phase windings.
DC machines, Synchronous machines and Induction machines exhibit some of the above properties as given in the following table.
Indicate the correct combination from this table

DC Machine	Synchronous Machines	Induction Machines
(A) P,S	Q,T	R,U
(B) Q,U	P,T	R,S
(C) P,S	R,U	Q,T
(D) R,S	Q,U	P,T

MCQ 1.4.114 When stator and rotor windings of a 2-pole rotating electrical machine are excited, each would produce a sinusoidal mmf distribution in the airgap with peal values F_s and F_r respectively. The rotor mmf lags stator mmf by a space angle δ at any instant as shown in figure. Thus, half of stator and rotor surfaces will form one pole with the other half forming the second pole. Further, the direction of torque acting on the rotor can be clockwise or counter-clockwise.

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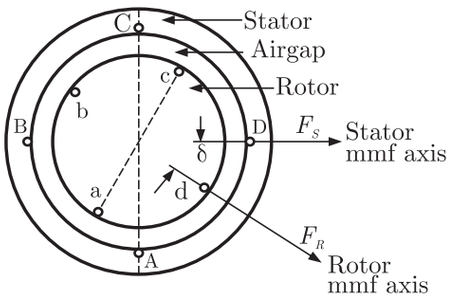

The following table gives four set of statement as regards poles and torque. Select the correct set corresponding to the mmf axes as shown in figure.

Stator Surface ABC forms	Stator Surface CDA forms	Rotor Surface abc forms	Rotor surface cda forms	Torque is
(A) North Pole	South Pole	North Pole	South Pole	Clockwise
(B) South Pole	North Pole	North Pole	South Pole	Counter Clockwise
(C) North Pole	South Pole	South Pole	North Pole	Counter Clockwise
(D) South Pole	North Pole	South Pole	North Pole	Clockwise

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MCQ 1.4.115 A 4-pole, 3-phase, double-layer winding is housed in a 36-slot stator for an ac machine with 60c phase spread. Coil span is 7 short pitches. Number of slots in which top and bottom layers belong to different phases is

(A) 24 (B) 18

(C) 12 (D) 0

MCQ 1.4.116 A 3-phase induction motor is driving a constant torque load at rated voltage and frequency. If both voltage and frequency are halved, following statements relate to the new condition if stator resistance, leakage reactance and core loss are ignored

1. The difference between synchronous speed and actual speed remains same
2. The airgap flux remains same
3. The stator current remains same
4. The p.u. slip remains same

Among the above, current statements are

(A) All (B) 1, 2 and 3

(C) 2, 3 and 4 (D) 1 and 4

MCQ 1.4.117 A single-phase induction motor with only the main winding excited would exhibit the following response at synchronous speed

(A) Rotor current is zero

(B) Rotor current is non-zero and is at slip frequency

(C) Forward and backward rotaling fields are equal

(D) Forward rotating field is more than the backward rotating field

MCQ 1.4.118 A dc series motor driving and electric train faces a constant power load. It is running at rated speed and rated voltage. If the speed has to be brought down to 0.25 p.u. the supply voltage has to be approximately brought down to

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(A) 0.75 p.u (B) 0.5 p.u

(C) 0.25 p.u (D) 0.125 p.u

YEAR 2002 ONE MARK

MCQ 1.4.119 If a 400 V, 50 Hz, star connected, 3-phase squirrel cage induction motor is operated from a 400 V, 75 Hz supply, the torque that the motor can now provide while drawing rated current from the supply

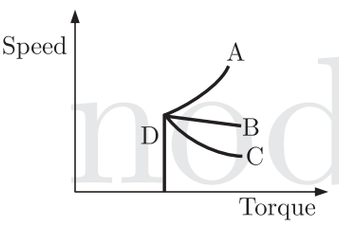
(A) reduces

(B) increases

(C) remains the same

(D) increases or reduces depending upon the rotor resistance

MCQ 1.4.120 A dc series motor fed from rated supply voltage is over-loaded and its magnetic circuit is saturated. The torque-speed characteristic of this motor will be approximately represented by which curve of figure ?



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(A) Curve A (B) Curve B

(C) Curve C (D) Curve D

MCQ 1.4.121 A 1 kVA, 230 V/100 V, single phase, 50 Hz transformer having negligible winding resistance and leakage inductance is operating under saturation, while 250 V, 50 Hz sinusoidal supply is connected to the high voltage winding. A resistive load is connected to the low voltage winding which draws rated current. Which one of the following quantities will not be sinusoidal ?

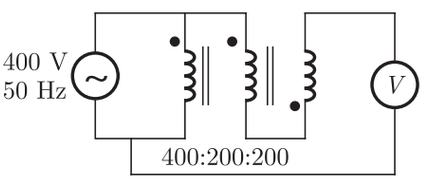
(A) Voltage induced across the low voltage winding

(B) Core flux

(C) Load current

(D) Current drawn from the source

MCQ 1.4.122 A 400 V / 200 V / 200 V, 50 Hz three winding transformer is connected as shown in figure. The reading of the voltmeter, V, will be



(A) 0 V (B) 400 V

(C) 600 V (D) 800 V

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YEAR 2002 TWO MARK

MCQ 1.4.123 A 200 V, 2000 rpm, 10 A, separately excited dc motor has an armature resistance of 2 Ω. Rated dc voltage is applied to both the armature and field winding of the motor. If the armature drawn 5 A from the source, the torque developed by the motor is

(A) 4.30 Nm (B) 4.77 Nm

(C) 0.45 Nm (D) 0.50 Nm

MCQ 1.4.124 The rotor of a three phase, 5 kW, 400 V, 50 Hz, slip ring induction motor is wound for 6 poles while its stator is wound for 4 poles. The approximate average no load steady state speed when this motor is connected to 400 V, 50 Hz supply is

(A) 1500 rpm (B) 500 rpm

(C) 0 rpm (D) 1000 rpm

MCQ 1.4.125 The flux per pole in a synchronous motor with the field circuit ON and the stator disconnected from the supply is found to be 25 mWb. When the stator is connected to the rated supply with the field excitation unchanged, the flux per pole in the machine is found to be 20 mWb while the motor is running on no load. Assuming no load losses to be zero, the no load current drawn by the motor from the supply

(A) lags the supply voltage

(B) leads the supply voltage

(C) is in phase with the supply voltage

(D) is zero

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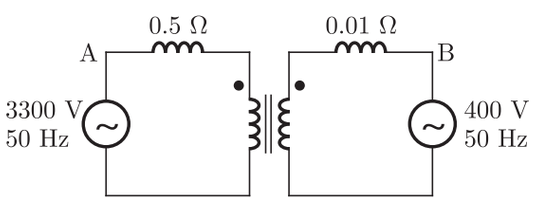
MCQ 1.4.126 *A 230 V, 250 rpm, 100 A separately excited dc motor has an armature resistance of 0.5 Ω. The motor is connected to 230 V dc supply and rated dc voltage is applied to the field winding. It is driving a load whose torque-speed characteristic is given by $T_L = 500 - 10\,\omega$, where ω is the rotational speed expressed in rad/sec and T_L is the load torque in Nm. Find the steady state speed at which the motor will drive the load and the armature current drawn by it from the source. Neglect the rotational losses of the machine.

MCQ 1.4.127 *A single phase 6300 kVA, 50 Hz, 3300 V/ 400 V distribution transformer is connected between two 50 Hz supply systems, A and B as shown in figure. The transformer has 12 and 99 turns in the low and high voltage windings respectively. The magnetizing reactance of the transformer referred to the high voltage side is 500 Ω. The leakage reactance of the high and low voltage windings are 1.0 Ω and 0.012 Ω respectively. Neglect the winding resistance and core losses of the transformer. The Thevenin voltage of system A is 3300 V while that of system B is 400 V. The short circuit reactance of system A and B are 0.5 Ω and 0.010 Ω respectively. If no power is transferred between A and B, so that the two system voltages are in phase, find the magnetizing ampere turns of the transformer.



MCQ 1.4.128 *A 440 V, 50 Hz, 6 pole, 960 rpm star connected induction machine has the

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following per phase parameters referred to the stator :

$$R_s = 0.6\ \Omega, R_r = 0.3\ \Omega, X_s = 1\ \Omega$$

The magnetizing reactance is very high and is neglected. The machine is connected to the 440 V, 50 Hz supply and a certain mechanical load is coupled to it. It is found that the magnitude of the stator current is equal to the rated current of the machine but the machine is running at a speed higher than its rated speed. Find the speed at which the machine is running. Also find the torque developed by the machine.

MCQ 1.4.129 A 415 V, 2-pole, 3-phase, 50 Hz, star connected, non-salient pole synchronous motor has synchronous reactance of 2 Ω per phase and negligible stator resistance. At a particular field excitation, it draws 20 A at unity power factor from a 415 V, 3-phase, 50 Hz supply. The mechanical load on the motor is now increased till the stator current is equal to 50 A. The field excitation remains unchanged. Determine :

(a) the per phase open circuit voltage E_0

(b) the developed power for the new operating condition and corresponding power factor.

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MCQ 1.4.130 The core flux of a practical transformer with a resistive load

(A) is strictly constant with load changes

(B) increases linearly with load

(C) increases as the square root of the load

(D) decreases with increased load

MCQ 1.4.131 X_d, X'_d and X''_d are steady state d-axis synchronous reactance, transient d-axis reactance and sub-transient d-axis reactance of a synchronous machine respectively. Which of the following statements is true ?

(A) $X_d > X'_d > X''_d$ (B) $X''_d > X'_d > X_d$

(C) $X'_d > X''_d > X_d$ (D) $X_d > X''_d > X'_d$

MCQ 1.4.132 A 50 Hz balanced three-phase, Y-connected supply is connected to a balanced three-phase Y-connected load. If the instantaneous phase-a of the supply voltage is $V\cos(\omega t)$ and the phase-a of the load current is $I\cos(\omega t - \phi)$, the instantaneous three-phase power is

(A) a constant with a magnitude of $VI\cos\phi$

(B) a constant with a magnitude of $(3/2)\,VI\cos\phi$

(C) time-varying with an average value of $(3/2)\,VI\cos\phi$ and a frequency of 100 Hz

(D) time-varying with an average value of $VI\cos\phi$ and a frequency of 50 Hz

MCQ 1.4.133 In the protection of transformers, harmonic restraint is used to guard against

(A) magnetizing inrush current (B) unbalanced operation

(C) lightning (D) switching over-voltages

MCQ 1.4.134 In case of an armature controlled separately excited dc motor drive with closed-loop speed control, an inner current loop is useful because it

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(A) limits the speed of the motor to a safe value

(B) helps in improving the drive energy efficiency

(C) limits the peak current of the motor to the permissible value

(D) reduces the steady state speed error

YEAR 2001 TWO MARK

MCQ 1.4.135 An electric motor with "constant output power" will have a torque-speed characteristics in the form of a

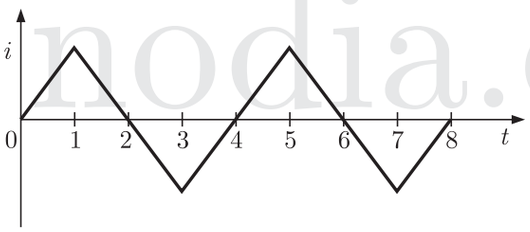
(A) straight line through the origin

(B) straight line parallel to the speed axis

(C) circle about the origin

(D) rectangular hyperbola

MCQ 1.4.136 *An ideal transformer has a linear B/H characteristic with a finite slope and a turns ratio of 1 : 1. The primary of the transformer is energized with an ideal current source, producing the signal i as shown in figure. Sketch the shape (neglecting the scale factor) of the following signals, labeling the time axis clearly



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(a) the core flux ϕ_{oc} with the secondary of the transformer open

(b) the open-circuited secondary terminal voltage $v_2(t)$

(c) the short-circuited secondary current $i_2(t)$, and

(d) the core flux ϕ_{sc} with the secondary of the transformer short-circuited

MCQ 1.4.137 *In a dc motor running at 2000 rpm, the hysteresis and eddy current losses are 500 W and 200 W respectively. If the flux remains constant, calculate the speed at which the total iron losses are halved.

MCQ 1.4.138 *A dc series motor is rated 230 V, 1000 rpm, 80 A (refer to figure). The series field resistance is 0.11 Ω, and the armature resistance is 0.14 Ω. If the flux at an armature current of 20 A is 0.4 times of that under rated condition, calculate the speed at this reduced armature current of 20 A.

MCQ 1.4.139 *A 50 kW synchronous motor is tested by driving it by another motor. When the excitation is not switched on, the driving motor takes 800 W. When the armature is short-circuited and the rated armature current of 10 A is passed through it, the driving motor requires 2500 W. On open-circuiting the armature with rated excitation, the driving motor takes 1800 W. Calculate the efficiency of the synchronous motor at 50% load. Neglect the losses in the driving motor.

MCQ 1.4.140 *Two identical synchronous generators, each of 100 MVA, are working in parallel supplying 100 MVA at 0.8 lagging p.f. at rated voltage. Initially the machines are sharing load equally. If the field current of first generator is reduced by 5% and of

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the second generator increased by 5%, find the sharing of load (MW and MVAR) between the generators.

Assume $X_d = X_q = 0.8$ p.u, no field saturation and rated voltage across load. Reasonable approximations may be made.

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SOLUTION

SOL 1.4.1 Option (D) is correct.

Leakage flux in an induction motor is flux that linked the stator winding or the rotor winding but not both.

SOL 1.4.2 Option (D) is correct.

The angle δ in the swing equation of a synchronous generator is the angular displacement of an axis fixed to the rotor with respect to a synchronously rotating axis.

SOL 1.4.3 Option (C) is correct.

Since, the no-load loss (when load is not connected) is 64 W. So, the open circuit loss is

$$W_0 = 6 \text{ watt (no load)}$$

As the 90% of rated current flows in its both LV and HV windings, the lost is measured as

$$\text{copper loss at } 90\% \text{ load} = 81 \text{ watt}$$

or, $$W_{cu}(at\ 90\%) = 81 \text{ watt}$$

Now, we have the copper loss for x load as

$$W_{cu}(x) = W_{cu}(\text{at full load}) \times \left(\frac{I_x}{I_{FL}}\right)^2$$

or, $$W_{cu}(\text{at full load}) = W_{cu}(\text{at } x\% \text{ load}) \times \left(\frac{I_{FL}}{I_x}\right)^2$$

$$= (81) \times \frac{1}{(0.9)^2}$$

$$= 100 \text{ watt}$$

For maximum efficiency we must have

$$\text{copper lossed} = \text{no-load loss}$$

$$= 64 \text{ watt}$$

Consider at $x\%$ load copper loss is 64 watt. So,

$$(x^2) W_{cu}(\text{at full load}) = 64$$

or, $$x = \sqrt{\frac{64}{100}} = 0.8$$

or $$x = 80\% \text{ load}$$

SOL 1.4.4 Option (B) is correct.

Given,

frequency of source, $f = 50 \text{ Hz}$

no. of poles $P = 4$

rotating speed $N = 1440 \text{ rpm}$

Now, the synchronous speed is determined as

$$N_S = \frac{120f}{P}$$

$$= \frac{120}{4}(50) = 1500 \text{ rpm}$$

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So, the slip in the motor is

$$S = \frac{N_S - N}{N_S}$$
$$= \frac{1500 - 1440}{1500} = 0.04$$

Now, the electrical frequency of the induced negative sequence current in rotor is obtained as

$$f_0 = (2 - 5)f$$

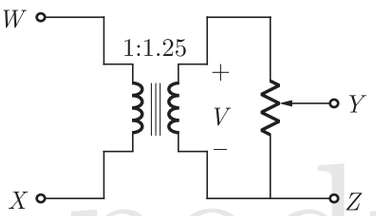
where f is stator frequency given as $f = 50\,\text{Hz}$.

Therefore, $f_0 = (2 - 0.04)50 = 98\,\text{Hz}$

SOL 1.4.5 Option (C) is correct.

For the given transformer, we have

$$\frac{V}{V_{WX}} = \frac{1.25}{1}$$



Since, $\frac{V_{YZ}}{V} = 0.8$ (attenuation factor)

So, $\frac{V_{YZ}}{V_{WX}} = (0.8)(1.25) = 1$

or, $V_{YZ} = V_{WX}$

at $V_{WX_1} = 100\,\text{V};\ \frac{V_{YZ_1}}{V_{WX_1}} = \frac{100}{100}$

at $V_{WZ_2} = 100\,\text{V};\ \frac{V_{WX_2}}{V_{YZ_2}} = \frac{100}{100}$

SOL 1.4.6 Option (D) is correct.

Slip is given as $S = \frac{n_s - n}{n_s}$

where, n_s = synchronous speed

n = rotor speed

Thus, slip depend on synchronous speed and the rotor speed. Also, torque increases with increasing slip up to a maximum value and then decreases. Slip does not depend on core/loss component.

SOL 1.4.7 Option (D) is correct.

$$E \propto n\phi$$

where $n \rightarrow$ speed, $\phi \rightarrow$ flux and $E \rightarrow$ back emf

Given that, $V_t = 250\,\text{V},\ R_a = 0.25\,\Omega$

$n_1 = 1000\,\text{rpm},\ I_{L1} = 68\,\text{A},\ I_{F1} = 2.2\,\text{A}$

Armature current, $I_{a1} = I_{L1} - I_{F1} = 68 - 2.2 = 65.8\,\text{A}$

$E_1 = V_t - I_a, R_a$

$= 250 - (65.8)(0.25) = 203.55\,\text{V}$

Now, $n_2 = 1600\,\text{rpm},\ I_{L2} = 52.8\,\text{A},\ I_{F2} = 1.8\,\text{A}$

Armature current, $I_{a_2} = I_{L2} - I_{F2} = 52.8 - 1.8 = 51\,\text{A}$

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$$E_2 = V_t - I_{a_2} R_a = 220 - (51)(0.25) = 207.25\ \text{V}$$

$$\frac{E_1}{E_2} = \left(\frac{n_1}{n_2}\right)\left(\frac{\phi_1}{\phi_2}\right)$$

$$\frac{203.55}{207.45} = \left(\frac{1000}{1600}\right)\left(\frac{\phi_1}{\phi_2}\right)$$

$$\phi_2 = 0.6369\phi_1$$

$$\%\ \text{reduce in flux} = \frac{\phi_1 - \phi_2}{\phi_1} \times 100 = \frac{\phi_1 - 0.6369\phi_1}{\phi_1} \times 100$$

$$\simeq 36.3\%$$

SOL 1.4.8 Option (B) is correct.

Given that magnetizing current and losses are to be neglected. Locked rotor line current.

$$I_2 = \frac{E_2}{Z_2} = \frac{E_2}{\sqrt{R_2^2 + X_2^2}} \qquad (R_2 = 0)$$

$$I_2 = \frac{E_2}{X_2} = \frac{E_2}{\omega L_2} \propto \frac{E_2}{f}$$

So

$$\frac{50}{I_2'} = \left(\frac{230}{236}\right)\left(\frac{57}{50}\right)$$

$$I_2' = 45.0\ \text{A}$$

SOL 1.4.9 Option (B) is correct.

Since the core length of the second transformer is $\sqrt{2}$ times of the first, so the core area of the second transformer is twice of the first.

Let subscript 1 is used for first transformer and 2 is used for second transform.

Area $a_2 = 2a_1$

Length $l_2 = \sqrt{2}\, l_1$

Magnetizing inductance, $L = \dfrac{N^2 \mu a}{l}$

N = no. of turns

μ = length of flux path

a = cross section area

l = length

$$L \propto \frac{a}{l}$$

N and μ are same for both the transformer

$$\frac{L_1}{L_2} = \frac{a_1}{a_2} \cdot \frac{l_2}{l_1}$$

$$\frac{L_1}{L_2} = \frac{a_1}{2a_1} \cdot \frac{\sqrt{2}\, l_1}{l_1}$$

$$L_2 = \sqrt{2}\, L_1$$

Thus, magnetizing reactance of second transformer is $\sqrt{2}$ times of first.

Magnetizing current $X_{m2} = \sqrt{2}\, X_{m1}$

$$I_m = \frac{V}{X_m}$$

$$\frac{I_{m1}}{I_{m2}} = \frac{V_1}{V_2} \cdot \frac{X_{m2}}{X_{m1}} = \left(\frac{V_1}{2V_1}\right)\left(\frac{\sqrt{2}\, X_{m1}}{X_{m1}}\right) \qquad (V_2 = 2V_1)$$

$$I_{m2} = \sqrt{2}\, I_{m1}$$

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Thus, magnetizing current of second transformer

$$I_{m2} = \sqrt{2} \times 0.5 = 0.707 \text{ A}$$

Since voltage of second transformer is twice that of first and current is $\sqrt{2}$ times that of first, so power will be $2\sqrt{2}$ times of first transformer.

$$P_2 = 2\sqrt{2} \times 55 = 155.6 \text{ W}$$

SOL 1.4.10 Option (A) is correct.

The armature current of DC shunt motor

$$I_a = \frac{V - E_b}{R_a}$$

at the time of starting, $E_b = 0$. If the full supply voltage is applied to the motor, it will draw a large current due to low armature resistance.

A variable resistance should be connected in series with the armature resistance to limit the starting current.

A 4-point starter is used to start and control speed of a dc shut motor.

SOL 1.4.11 Option (B) is correct.

The Back emf will go to zero when field is reduced, so Current input will be increased. But when Field increases (though in reverse direction) the back emf will cause the current to reduce.

SOL 1.4.12 Option (C) is correct.

An air-core transformer has linear B-H characteristics, which implies that magnetizing current characteristic will be perfectly sinusoidal.

SOL 1.4.13 Option (A) is correct.

Initially $E_{b_1} = V - I_a R_a = 220 - 1 \times 10 = 210 \text{ V}$

Now the flux is reduced by 10% keeping the torque to be constant, so the current will be

$$I_{a_1}\phi_1 = I_{a_2}\phi_2$$

$$I_{a_2} = I_{a_1}\frac{\phi_1}{\phi_2} = 10 \times \frac{1}{0.9} = 11.11 \text{ A} \qquad \therefore \ \phi_2 = 0.9\phi_1$$

$$E_b \propto N\phi$$

$$\Rightarrow \quad \frac{E_{b_2}}{E_{b_1}} = \frac{N_2\phi_2}{N_1\phi_1} = 0.9 \qquad N_1 = N_2$$

$$E_{b_2} = 0.9E_{b_1} = 0.9 \times 210 = 189 \text{ V}$$

Now adding a series resistor R in the armature resistor, we have

$$E_{b_2} = V - I_{a_2}(R_a + R)$$

$$189 = 220 - 11.11(1 + R)$$

$$R = 1.79 \ \Omega$$

SOL 1.4.14 Option ( ) is correct.

The steady state speed of magnetic field

$$n_s = \frac{120 \times 50}{6} = 1000 \text{ rpm}$$

Speed of rotor $n_r = (1 - S)n_s \qquad S = 0.05$

$$= 0.95 \times 1000 = 950 \text{ rpm}$$

In the steady state both the rotor and stator magnetic fields rotate in synchronism , so the speed of rotor field with respect to stator field would be zero.

Speed of rotor which respect to stator field

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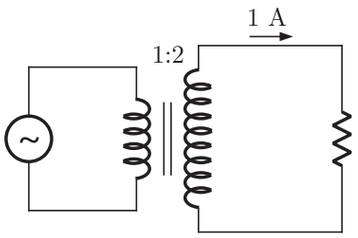
$$= n_r - n_s = 950 - 1000 = -50 \text{ rpm}$$

None of the option matches the correct answer.

SOL 1.4.15 Option (C) is correct.

Given



$$I_0 = 1 \text{ amp (magnetizing current)}$$

Primary current $I_P = ?$

$$I_2 = 1 \text{ A}$$

$$I_2' = \text{secondary current reffered to Primary}$$

$$= \frac{2}{1} \times 1 = 2 \text{ amp}$$

$$I_P = \sqrt{i_0^2 + i_2^2} = \sqrt{1+4} = \sqrt{5} = 2.24 \text{ Amp}$$

SOL 1.4.16 Option ( ) is correct.

SOL 1.4.17 Option (C) is correct.

Synchronize speed of induction machine

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

Speed of machine = 1600 rpm

= Actual speed of induction machine

$$\text{slip} = \frac{1500 - 1600}{1500} = \frac{-1}{15} = -0.066 \text{(negative)}$$

Hence induction machine acts as induction generator and dc machine as dc motor.

SOL 1.4.18 Option ( ) is correct.

SOL 1.4.19 Option (B) is correct.

Given no-load speed $N_1 = 1500$ rpm

$$V_a = 200 \text{ V}, T = 5 \text{ Nm}, N = 1400 \text{ rpm}$$

emf at no load

$$E_{b1} = V_a = 200 \text{ V}$$

$$N \propto E_b \Rightarrow \frac{N_1}{N_2} = \frac{E_{b_1}}{E_{b_2}}$$

$$E_{b_2} = \left(\frac{N_2}{N_1}\right) E_{b_1} = \frac{1400}{1500} \times 200 = 186.67 \text{ V}$$

$$T = E_b (I_a/\omega) \Rightarrow \frac{186.67 \times 60}{2\pi \times 1400} I_a = 5$$

$$I_a = 3.926 \text{ A}$$

$$V = E_b + I_a R_a$$

$$R_a = \frac{V_a - E_b}{I_a} = \frac{200 - 186.67}{3.926} = 3.4 \ \Omega$$

SOL 1.4.20 Option (B) is correct.

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$$T = 2.5 \text{ Nm at } 1400 \text{ rpm}$$

than $V = ?$

$$T = \frac{E_b I_b}{\omega}$$

$$2.5 = \frac{186.6 \times I_a \times 60}{2\pi \times 1400}$$

$$I_a = 1.963 \text{ A}$$

$$V = E_b + I_a R_a = 186.6 + 1.963 \times 3.4 = 193.34 \text{ V}$$

SOL 1.4.21 Option (D) is correct.

Given field excitation of = 20 A

Armature current = 400 A

Short circuit and terminal voltage = 200 V

On open circuit, load current = 200 A

So, Internal resistance $= \frac{2000}{400} = 5\,\Omega$

Internal vol. drop $= 5 \times 200$

$= 1000$ V

SOL 1.4.22 Option (C) is correct.

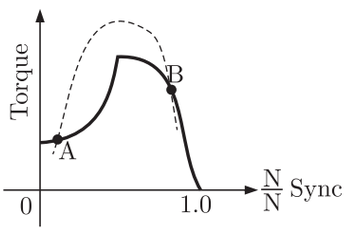
Given single-phase iron core transformer has both the vertical arms of cross section area 20 cm^2, and both the horizontal arms of cross section are 10 cm^2

So, Inductance $= \frac{NBA}{1}$ (proportional to cross section area)

When cross section became half, inductance became half.

SOL 1.4.23 Option (A) is correct.

Given 3-phase squirrel cage induction motor.



At point A if speed ↑, Torque ↑

speed ↓, Torque ↓

So A is stable.

At point B if speed ↑ Load torque ↓

So B is un-stable.

SOL 1.4.24 Option ( ) is correct.

SOL 1.4.25 Option (D) is correct.

Peak voltage across A and B with S open is

$$V = m\frac{di}{dt} = m \times (\text{slope of } I - t)$$

$$= \frac{400}{\pi} \times 10^{-3} \times \left[\frac{10}{5 \times 10^{-3}}\right] = \frac{800}{\pi} \text{ V}$$

SOL 1.4.26 Option ( ) is correct.

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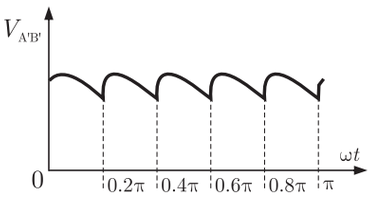
SOL 1.4.27 Option (A) is correct.

Wave form $V_{A'B'}$



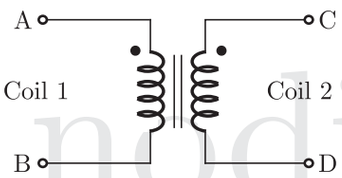
SOL 1.4.28 Option (B) is correct.

When both S1 and S2 open, star connection consists 3rd harmonics in line current due to hysteresis A saturation.

SOL 1.4.29 Option (A) is correct.

Since S2 closed and S1 open, so it will be open delta connection and output will be sinusoidal at fundamental frequency.

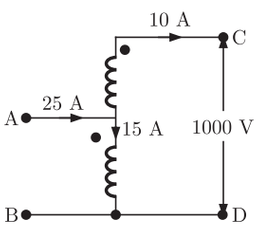
SOL 1.4.30 Option (A) is correct.



$$N_1 = 4000$$
$$N_2 = 6000$$
$$I = 25 \text{ A}$$
$$V = 400 \text{ V}, f = 50 \text{ Hz}$$

Coil are to be connected to obtain a single Phase, $\frac{400}{1000}$ V auto transfer to drive Load 10 kVA

Connected A & D common B



SOL 1.4.31 Option (D) is correct.

Given 3-phase, 400 V, 5 kW, Star connected synchronous motor.

Internal Resistance $= 10\,\Omega$

Operating at 50% Load, unity p.f.

So

$$\text{kVA rating} = 25 \times 400 = 1000$$

Internal Resistance $= 10\ \Omega$

So

$$\text{kVA rating} = 1000 \times 10 = 10000 \text{ kVA}$$

SOL 1.4.32 Option (D) is correct.

Distributed winding and short chording employed in AC machine will result in

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reduction of emf and harmonics.

SOL 1.4.33 Option (B) is correct.
Transformer connection will be represented by Y d1.

SOL 1.4.34 Option (D) is correct.
Detent torque/Restraining toque:
The residual magnetism in the permanent magnetic material produced.
The detent torque is defined as the maximum load torque that can be applied to the shaft of an unexcited motor without causing continuous rotation. In case the motor is unexcited.

SOL 1.4.35 Option (D) is correct.
Given: 1-ϕ transformer, 230 V/115 V, 2 kVA
W_1 : 250 V, 10 A, Low Power Factor
W_2 : 250 V, 5 A, Low Power Factor
W_3 : 150 V, 10 A, High Power Factor
W_4 : 150 V, 5 A, High Power Factor
In one circuit test the wattmeter W_2 is used and in short circuit test of transformer W_3 is used.

SOL 1.4.36 Option (B) is correct.
Given: 230 V, 50 Hz, 4-Pole, 1-ϕ induction motor is rotating in clock-wise(forward) direction

$$N_s = 1425 \text{ rpm}$$

Rotar resistance at stand still$(R_2) = 7.8\ \Omega$

So

$$N_s = \frac{120 \times 50}{4} = 1500$$

$$\text{Slip}(S) = \frac{1500 - 1425}{1500} = 0.05$$

$$\text{Resistance in backward branch } r_b = \frac{R_2}{2 - S} = \frac{7.8}{2 - 0.05} = 4\ \Omega$$

SOL 1.4.37 Option (C) is correct.
Given: a 400 V, 50 Hz, 30 hp, 3-ϕ induction motor
Current = 50 A at 0.8 p.f. lagging
Stator and rotor copper losses are 1.5 kW and 900 W
fraction and windage losses= 1050 W

$$\text{Core losses} = 1200\ \text{W} = 1.2\ \text{kW}$$

So,

$$\text{Input power in stator} = \sqrt{3} \times 400 \times 50 \times 0.8 = 27.71\ \text{kW}$$

$$\text{Air gap power} = 27.71 - 1.5 - 1.2 = 25.01\ \text{kW}$$

SOL 1.4.38 Option (A) is correct.

$$\text{Induced emf in secondary} = -N_2 \frac{d\phi}{dt}$$

$$\text{During } -0 < t < 1, \qquad E_1 = -(100)\frac{d\phi}{dt} = -12\ \text{V}$$

E_1 and E_2 are in opposition

$$E_2 = 2E_1 = 24\ \text{V}$$

During time $1 < t < 2$, $\frac{d\phi}{dt} = 0$, then $E_1 = E_2 = 0$

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During $2 < t < 2.5$, $\quad E_1 = -(100)\dfrac{d\phi}{dt} = -24$ V

Then $\quad E_2 = -0 - 48$ V

SOL 1.4.39 Option (B) is correct.

Given 400 V, 50 Hz, 4-Pole, 1400 rpm star connected squirrel cage induction motor.

$$R = 1.00\ \Omega, X_s = X'_r = 1.5\ \Omega$$

So,

For max. torque slip

$$S_m = \frac{R'_r}{X_{sm} + X'_{rm}}$$

For starting torque $S_m = 1$

Then $\quad X_{sm} + X'_{rm} = R'_r$

$$2\pi f_m L_s + 0.2\pi f_m L'_r = 1$$

Frequency at max. torque

$$f_m = \frac{1}{2\pi(L_s + L'_r)}$$

$$L_s = \frac{X_s}{2\pi \times 50} = \frac{1.5}{2\pi \times 50}$$

$$L'_r = \frac{1.5}{2\pi \times 50}$$

$$f_m = \frac{1}{\frac{1.5}{50} + \frac{1.5}{50}} = \frac{50}{3} = 16.7 \text{ Hz}$$

In const V/f control method

$$\frac{V_1}{f_1} = \frac{400}{50} = 8$$

$$\frac{V_2}{f_1} = 8$$

So $\quad V_2 = f_2 \times 8 = 16.7 \times 8 = 133.3$ V

Hence (B) is correct option.

SOL 1.4.40 Option (A) is correct.

Given 3-ϕ, 440 V, 50 Hz, 4-Pole slip ring motor

Motor is coupled to 220 V

$$N = 1410 \text{ rpm}, W_1 = 1800 \text{ W}, W_2 = 200 \text{ W}$$

So, $\quad N_s = \dfrac{120f}{P} = \dfrac{120 \times 50}{4} = 1500$ rpm

Relative speed $= 1500 - 1410$

$= 90$ rpm in the direction of rotation.

SOL 1.4.41 Option (C) is correct.

Neglecting losses of both machines

$$\text{Slip}(S) = \frac{N_s - N}{N_s} = \frac{1500 - 1410}{1500} = 0.06$$

total power input to induction motor is

$$P_{\text{in}} = 1800 - 200 = 1600 \text{ W}$$

Output power of induction motor

$$P_{\text{out}} = (1 - S)P_{\text{in}} = (1 - 0.06)1600 = 1504 \text{ W}$$

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Losses are neglected so dc generator input power = output power

$$= 1504 \text{ W}$$

So, $$I^2R = 1504$$

$$I = \sqrt{\frac{1504}{10}} = 12.26 \text{ A}$$

SOL 1.4.42 Option (D) is correct.

Given: $V = 240$ V, dc shunt motor

$$I = 15 \text{ A}$$

$$\text{Rated load at a speed} = 80 \text{ rad/s}$$

$$\text{Armature Resistance} = 0.5\ \Omega$$

$$\text{Field winding Resistance} = 80\ \Omega$$

So, $$E = 240 - 12 \times 0.5 = 234$$

$$V_{\text{plugging}} = V + E = 240 + 234 = 474 \text{ V}$$

SOL 1.4.43 Option (A) is correct.

External Resistance to be added in the armature circuit to limit the armature current to 125%.

So $$I_a = 12 \times 1.25 = \frac{474}{R_a + R_{\text{external}}}$$

$$R_a + R_{\text{external}} = 31.6$$

$$R_{\text{external}} = 31.1\ \Omega$$

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SOL 1.4.44 Option (D) is correct.

A synchronous motor is connected to an infinite bus at 1.0 p.u. voltage and 0.6 p.u. current at unity power factor. Reactance is 1.0 p.u. and resistance is negligible.

So,

$$V = 1\angle 0^\circ \text{ p.u.}$$

$$I_a = 0.6\angle 0^\circ \text{ p.u.}$$

$$Z_s = R_a + jX_s = 0 + j1 = 1\angle 90^\circ \text{ p.u.}$$

$$V = E\angle\delta + I_aZ_s = 1\angle 0^\circ - 0.6\angle 0^\circ \times 1\angle 90^\circ$$

$$E\angle\delta = 1.166\angle -30.96^\circ \text{ p.u.}$$

Excitation voltage $= 1.17$ p.u.

Load angle (δ) $= 30.96^\circ$(lagging)

SOL 1.4.45 Option ( ) is correct.

SOL 1.4.46 Option (C) is correct.

In transformer zero voltage regulation at full load gives leading power factor.

SOL 1.4.47 Option (B) is correct.

Speed-armature current characteristic of a dc motor is shown as following

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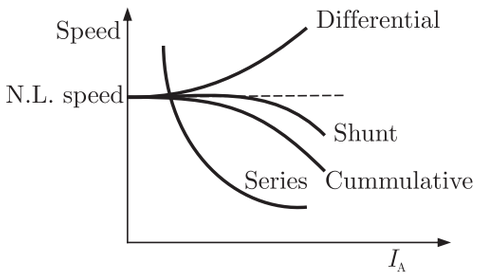


The shunt motor provides speed regulation at full load without any controller.

SOL 1.4.48 Option (C) is correct.
From the given characteristics point A and D are stable

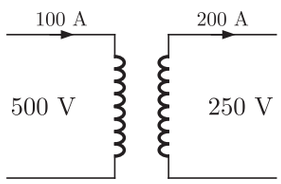
SOL 1.4.49 Option (B) is correct.
When the 3-ϕ synchronous motor running at full load and unity power factor and shaft load is reduced half but field current is constant then it gives leading power factor.

SOL 1.4.50 Option (A) is correct.
Given star connected synchronous machine, $P = 100$ kVA
Open circuit voltage $V = 415$ V and field current is 15 A, short circuit armature current at a field current of 10 A is equal to rated armature current.
So,
Line synchronous impedance

$$= \frac{\text{open circuit line voltage}}{\sqrt{3} \times \text{short ckt phase current}}$$

$$= \frac{415}{\sqrt{3} \times \left(\frac{100 \times 1000}{\sqrt{3} \times 415}\right)} = 1.722$$

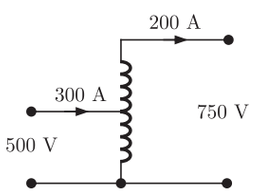
SOL 1.4.51 Option (C) is correct.
Given 1-ϕ transformer
$P = 50$ kVA, $V = 250$ V/500 V
Two winding transformer efficiency 95% at full load unity power factor.



Efficiency $95\% = \dfrac{50 \times 1 \times 1}{50 \times W_{cu} + W_i}$

So $W_{cu} + W_i = 2.631$

Reconfigured as a 500 V/750 V auto-transformer



auto-transformer efficiency

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$$\eta = \frac{150}{150 + 2.631} = 98.276\%$$

SOL 1.4.52 Option (B) is correct.

Given 3-ϕ, 3-stack

Variable reluctance step motor has 20-poles

$$\text{Step angle} = \frac{360}{3 \times 20} = 6^\circ$$

SOL 1.4.53 Option (D) is correct.

Given a 3-ϕ squirrel cage induction motor starting torque is 150% and maximum torque 300%

So

$$T_{\text{Start}} = 1.5\,T_{\text{FL}}$$

$$T_{\max} = 3\,T_{\text{FL}}$$

Then
$$\frac{T_{\text{Start}}}{T_{\max}} = \frac{1}{2} \quad \ldots(1)$$

$$\frac{T_{\text{Start}}}{T_{\max}} = \frac{2S_{\max}}{S^2{}_{\max} + 1^2} \quad \ldots(2)$$

from equation (1) and (2)

$$\frac{2S_{\max}}{S^2{}_{\max} + 1} = \frac{1}{2}$$

$$S_{\max}{}^2 - 4S_{\max} + 1 = 0$$

So
$$S_{\max} = 26.786\%$$

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SOL 1.4.54 Option (C) is correct.

Given 3-ϕ squirrel cage induction motor has a starting current of seven the full load current and full load slip is 5%

$$I_{\text{St}} = 7I_{\text{Fl}}$$

$$S_{\text{Fl}} = 5\%$$

$$\frac{T_{\text{St}}}{T_{\text{Fl}}} = \left(\frac{I_{\text{St}}}{T_{\text{Fl}}}\right)^2 \times x^2 \times S_{\text{Fl}}$$

$$1.5 = (7)^2 \times x^2 \times 0.05$$

$$x = 78.252\%$$

SOL 1.4.55 Option (B) is correct.

Star delta starter is used to start this induction motor

So

$$\frac{T_{\text{St}}}{T_{\text{Fl}}} = \frac{1}{3} \times \left(\frac{I_{\text{St}}}{I_{\text{Fl}}}\right)^2 \times S_{\text{Fl}} = \frac{1}{3} \times 7^2 \times 0.05$$

$$\frac{T_{\text{St}}}{T_{\text{Fl}}} = 0.816$$

SOL 1.4.56 Option (C) is correct.

Given starting torque is 0.5 p.u.

So,
$$\frac{T_{\text{St}}}{T_{\text{Fl}}} = \left(\frac{I_{sc}}{I_{\text{Fl}}}\right)^2 \times S_{\text{Fl}}$$

$$0.5 = \left(\frac{I_{sc}}{I_{\text{Fl}}}\right)^2 \times 0.05$$

Per unit starting current

$$\frac{I_{sc}}{I_{\text{Fl}}} = \sqrt{\frac{0.5}{0.05}} = 3.16 \text{ A}$$

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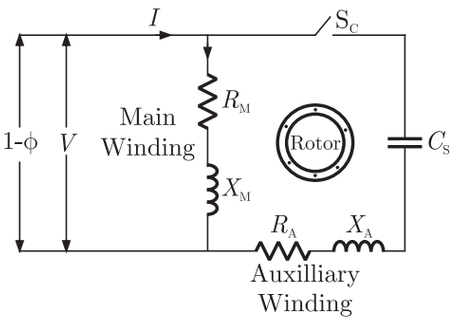
SOL 1.4.57 Option (D) is correct.
In transformer, in open circuit test, current is drawn at low power factor but in short circuit test current drawn at high power factor.

SOL 1.4.58 Option (B) is correct.
A single-phase capacitor start induction motor. It has cage rotor and its stator has two windings.



The two windings are displaced 90° in space. The direction of rotation can be changed by reversing the main winding terminals.

SOL 1.4.59 Option (B) is correct.
In DC motor, compensating winding is used for neutralizing armature reactance while interpole winding is used for improving commutation.
Interpoles generate voltage necessary to neutralize the e.m.f of self induction in the armature coils undergoing commutation. Interpoles have a polarity opposite to that of main pole in the direction of rotation of armature.

SOL 1.4.60 Option (A) is correct.
Given: A 230 V, DC machine, 20 A at 200 V as a generator.

$$R_a = 0.2\ \Omega$$

The machine operated as a motor at same terminal voltage and current, flux increased by 10%
So for generator

$$E_g = V + I_a R_a$$
$$= 200 + 20 \times 0.2$$
$$E_g = 204 \text{ volt}$$

for motor

$$E_m = V - I_a R_a$$
$$= 200 - 20 \times 0.2$$
$$E_m = 196 \text{ volt}$$

So

$$\frac{E_g}{E_m} = \frac{N_g}{N_m} \times \frac{\phi_g}{\phi_m}$$
$$\frac{204}{196} = \frac{N_g}{N_m} \times \frac{1}{1.1}$$
$$\frac{N_m}{N_g} = \frac{196}{204 \times 1.1} = 0.87$$

SOL 1.4.61 Option (B) is correct.
A synchronous generator is feeding a zero power factor(lagging) load at rated current then the armature reaction is demagnetizing.

SOL 1.4.62 Option (B) is correct.
Given the rating of first transformer is 500 kVA

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Per unit leakage impedance is 0.05 p.u.
Rating of second transformer is 250 kVA

So, Per unit impedance $= \dfrac{\text{actual impedance}}{\text{base impedance}}$

and, Per unit leakage impedance $\propto \dfrac{1}{\text{kVA}}$

Then $500\,\text{kVA} \times 0.05 = 250\ \text{kVA} \times x$

$$x = \frac{500}{250} \times 0.05 = 0.1\ \text{p.u.}$$

SOL 1.4.63 Option (C) is correct.
Given speed of a 4-pole induction motor is controlled by varying the supply frequency when the ratio of supply voltage and frequency is constant.
$f = 50$ Hz, $V = 400$ V, $N = 1440$ rpm

So $V \propto f$

$$\frac{V_1}{V_2} = \frac{f_1}{f_2}$$

$$V_2 = 400 \times \frac{30}{50} = 240\ \text{V}$$

$$T \propto \left(\frac{V^2}{f}\right)S$$

So $\dfrac{S_2}{S_1} = \left(\dfrac{V_1}{V_2}\right)^2 \times \dfrac{f_2}{f_1} \times \dfrac{T_2}{T_1}$

Given $T_1 = T_2$

Then $S_2 = 0.04 \times \left(\dfrac{400}{240}\right)^2 \times \dfrac{30}{50}$

$$S_2 = 0.066$$

$$N_r = N_s(1 - S)$$

$$N_r = \frac{120f}{P}$$

So $N_r = \dfrac{120 \times 30}{4}(1 - 0.066) = 840.6$ rpm

SOL 1.4.64 Option (A) is correct.
Given a 3-ϕ induction motor

$$P = 4,\ V = 400\ \text{V},\ f = 50\ \text{Hz}$$
$$r_1 = 1.0\ \Omega,\ r_2' = 0.5\ \Omega$$
$$X_1 = X'_2 = 1.2\ \Omega, X_m = 35\ \Omega$$

So, Speed of motor is

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500\ \text{rpm}$$

Torque

$$T_{st} = \frac{180}{2\pi N_s} \times \frac{V^2 r'_2}{(r_1 + r'_2)^2 + X^2}$$

$$= \frac{180}{2 \times 3.14 \times 1500} \times \frac{\left(\dfrac{400}{\sqrt{3}}\right)^2 \times 0.5}{(1.5)^2 + (2.4)^2}$$

$$= 63.58\ \text{Nm}$$

SOL 1.4.65 Option (B) is correct.

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Given that 3-ϕ induction motor star connected

$$P = 10 \text{ kW}, V = 400 \text{ V}, \text{Poles} = 4, f = 50 \text{ Hz}$$

Full load current $I_{\text{Fl}} = 20$ A

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}$$

So

Cu losses at full load

$$= \left(\frac{20}{15}\right)^2 \times 762 = 1354.67$$

$$\text{Total losses} = 1354.67 + 1002 = 2356.67$$

$$\text{Efficiency} = \frac{10000}{10000 + 2356.67} \times 100 = 81\%$$

SOL 1.4.66 Option (A) is correct.

Given 3-ϕ star connected synchronous motor

internal reactance $= 10\ \Omega$

Operating at 50% load, unity power factor, 400 V, 5 kW

Excitation increased $= 1\%$

So,

full load current

$$I_{\text{Fl}} = \frac{5 \times 10^3}{\sqrt{3} \times 400 \times 1} = 7.22$$

$$E^2 = (V\cos\theta - I_a R_a)^2 + (V\sin\theta - I_a X_s)^2$$

So, $$E = \sqrt{\left(\frac{400}{\sqrt{3}}\right)^2 + (10 \times 3.6)^2} = 2133.7289$$

Excitation will increase 1% then E_2

$$E_2 = 2133.7289 \times 0.01 = 236$$

$$I_a X = \sqrt{(E_2)^2 - V^2} = \sqrt{(236)^2 - \left(\frac{400}{\sqrt{3}}\right)^2} = 48.932$$

$$I_a = \frac{48.932}{10} = 4.8932$$

$$\text{Load}(\%) = \frac{4.8932}{7.22} = 67.83\ \%$$

SOL 1.4.67 Option (C) is correct.

Given $P = 4$, $f = 50$ Hz

Slots $= 48$, each coil has 10 turns

Short pitched by an angle(α) to 36° electrical

Flux per pole $= 0.05$ Wb

So,

$$E_{\text{ph}} = 4.44\ \text{f}\phi\text{T}_{\text{ph}} K_W$$

$$\text{Slot/Pole/ph} = \frac{48}{4 \times 3} = 4$$

$$\text{Slot/Pole} = \frac{48}{4} = 12$$

$$\text{Slot angle} = \frac{180}{12} = 15^\circ$$

$$K_d = \frac{\sin(4 \times 15/2)}{4\sin(15/2)} = 0.957$$

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$$K_p = \cos\frac{\alpha}{2} = \cos 18^\circ = 0.951$$

In double layer wdg

No. of coil = No of slots

$$\text{No. of turns/ph} = \frac{48 \times 10}{3} = 160$$

Then
$$E_{ph} = 4.44 \times 0.025 \times 50 \times 0.957 \times 0.951 \times 160$$
$$= 808 \text{ V}$$
$$E_L = \sqrt{3} \times 808$$
$$E_L = 1400 \text{ V (approximate)}$$

SOL 1.4.68 Option (A) is correct.

line to line induced voltage, so in 2 phase winding

$$\text{Slot/ pole/ph} = 6$$
$$T_{ph} = \frac{480}{2} = 240$$
$$\text{Slot angle} = \frac{180 \times 4}{48} = 15^\circ$$
$$K_d = \frac{\sin 6 \times (15/2)}{6 \sin(15/2)} = 0.903$$
$$K_p = \cos\left(\frac{36}{2}\right) = 0.951$$
$$E_{ph} = 4.44 \times 0.025 \times 50 \times 240 \times 0.951 \times 0.903$$
$$= 1143$$

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SOL 1.4.69 Option (A) is correct.

Fifth harmonic component of phase emf

So
$$\text{Angle} = \frac{180}{5} = 36^\circ$$

the phase emf of fifth harmonic is zero.

SOL 1.4.70 Option (C) is correct.

Given that: A 300 kVA transformer

Efficiency at full load is 95% and 0.8 p.f. lagging

96% efficiency at half load and unity power factor

So

For Ist condition for full load

$$95\% = \frac{\text{kVA} \times 0.8}{\text{kVA} \times 0.8 + W_{cu} + W_i} \quad \ldots(1)$$

Second unity power factor half load

$$96\% = \frac{\text{kVA} \times 0.5}{\text{kVA} \times 0.5 + W_{cu} + W_i} \quad \ldots(2)$$

So
$$W_{cu} + W_i = 12.63$$
$$0.25 W_{cu} + 0.96 W_i = 6.25$$

Then
$$W_{cu} = 8.51,\ W_i = 4.118$$

SOL 1.4.71 Option (B) is correct.

$$\text{Efficiency } (\eta) = \frac{X \times \text{p.f.} \times \text{kVA}}{X \times \text{kVA} + W_i + W_{cu} \times X^2}$$

So
$$X = \sqrt{\frac{4.118}{8.51}} = 0.6956$$

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$$\eta\% = \frac{0.6956 \times 1 \times 300}{0.6956 \times 300 + 4.118 + 8.51 \times (0.6956)^2}$$

$$\eta = 96.20\%$$

SOL 1.4.72 Option (D) is correct.

The leakage reactances X_1, and X_2' are equal and magnetizing reactance X_m is higher than X_1, and X_2'

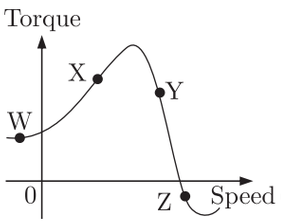
$$X_1 \approx X_2' << X_m$$

SOL 1.4.73 Option (B) is correct.

Three phase star delta connection of transformer induces a phase difference of 30° between output and input line voltage.

SOL 1.4.74 Option (A) is correct.

Given torque/speed curve of the induction motor



When the speed of the motor is in forward direction then slip varies from 0 to 1 but when speed of motor is in reverse direction or negative then slip is greater then 1. So at point W slip is greater than 1.

SOL 1.4.75 Option (B) is correct.

For an induction motor the ratio of gross power output to air-gap is equal to $(1 - s)$

So $$\frac{\text{gross power}}{\text{airgap power}} = (1 - s)$$

SOL 1.4.76 Option (A) is correct.

Given that two magnetic pole revolve around a stationary armature.

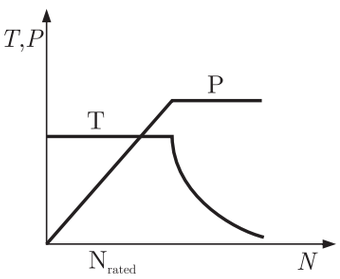
At c_1 the emf induced upward and no emf induced at c_2 and c_2'

SOL 1.4.77 Option (B) is correct.

Given A 50 kW DC shunt motor is loaded, then

at half the rated speed by armature voltage control

So $$P \propto N$$



$$P_{new} = \frac{50}{2} = 25 \text{ kW}$$

At 1.5 time the rated speed by field control

$$P = \text{constant}$$

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So $P = 50$ kW

SOL 1.4.78 Option (C) is correct.

In synchronous machine, when the armature terminal are shorted the field current should first be decreased to zero before started the alternator.

In open circuit the synchronous machine runs at rated synchronous speed. The field current is gradually increased in steps.

The short circuit ratio is the ratio of field current required to produced the rated voltage on open to the rated armature current.

SOL 1.4.79 Option (D) is correct.

In DC motor, $E = PN\phi\left(\frac{Z}{A}\right)$

or $E = K\phi\omega_n$

So armature emf E depends upon ϕ and ω only and torque developed depends upon

$$T = \frac{PZ\phi I_a}{2\pi A}$$

So, torque(T) is depends of ϕ and I_a and developed power(P) is depend of flux ϕ, speed ω and armature current I_a.

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SOL 1.4.80 Option ( ) is correct.

SOL 1.4.81 Option (B) is correct.

Given a three-phase cage induction motor is started by direct on line switching at rated voltage. The starting current drawn is 6 time the full load current.

Full load slip $= 4\%$

So

$$\left(\frac{T_{St}}{T_{Fl}}\right) = \left(\frac{I_{St}}{I_{Fl}}\right)^2 \times S_{Fl}$$
$$= (6)^2 \times 0.04 = 1.44$$

SOL 1.4.82 Option (B) is correct.

Given single-phase induction motor driving a fan load, the resistance rotor is high

So

$$E_b = V - I_a R_a \quad ...(1)$$
$$P_{mech} = E_a I_a$$
$$\tau = \frac{P_{mech}}{\omega_m} \quad ...(2)$$

From equation (1) and (2) the high resistance of rotor then the motor achieves quick acceleration and torque of starting is increase.

SOL 1.4.83 Option (A) is correct.

Given V/f control of induction motor, the maximum developed torque remains same

we have, $E = 4.44K_{w_1}f\phi T_1$

If the stator voltage drop is neglected the terminal voltage E_1. To avoid saturation and to minimize losses motor is operated at rated airgap flux by varying terminal voltage with frequency. So as to maintain (V/f) ratio constant at the rated value, the magnetic flux is maintained almost constant at the rated value which keeps maximum torque constant.

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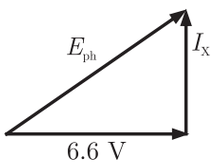
SOL 1.4.84 Option (B) is correct.

Given $P = 1000$ kVA, 6.6 kV

Reactance $= 20\ \Omega$ and neglecting the armature resistance at full load and unity power factor

So $P = \sqrt{3}\, V_L I_L$

$$I = \frac{1000}{\sqrt{3} \times 6.6} = 87.47 \text{ A}$$



So, $IX = 87.47 \times 20 = 1.75$ kV

$$E_{ph}^2 = \left(\frac{6.5}{\sqrt{3}}\right)^2 + (1.75)^2$$

$$E_{ph} = \sqrt{\left(\frac{6.5}{\sqrt{3}}\right)^2 + (1.75)^2}$$

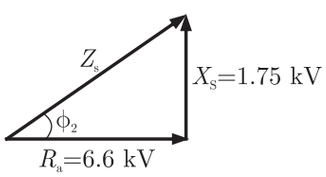
$$E_{ph} = 4.2 \text{ kV}$$

$E_L = \sqrt{3}\, E_{ph}$ $\because$ Star connection

$E_L = 1.732 \times 4.2 = 7.26$ kV

SOL 1.4.85 Option (C) is correct.

$$\text{Torque angle } \alpha_z = \tan^{-1}\left(\frac{X_s}{R_a}\right)$$



$$\alpha_z = \tan^{-1}\left(\frac{\sqrt{3} \times 1.75}{6.6}\right) = 24.6^\circ$$

SOL 1.4.86 Option (B) is correct.

Given that

Transformer rating is 500 kVA

Iron losses $= 300$ W

full load copper losses $= 600$ W

Maximum efficiency condition

$$W_i = X^2 W_c$$

So, $$X = \sqrt{\frac{W_i}{W_c}} = \sqrt{\frac{300}{600}} = 0.707$$

$$\text{efficiency}\% = 0.707 \times 100 = 70.7\%$$

SOL 1.4.87 Option (C) is correct.

Stepper motor is rotated in steps, when the supply is connected then the torque is produced in it. The higher value of torque is pull out torque and less torque

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when the torque is pull in torque.

SOL 1.4.88 Option (C) is correct.
The stepper motor has the permanent magnet rotor and stator has made of windings, it's connected to the supply.

SOL 1.4.89 Option (D) is correct.
1-phase induction motor is not self starting, so it's used to start different method at full load condition, capacitor-run type motor have higher power factor. In this type the capacitor is connected in running condition.

SOL 1.4.90 Option (C) is correct.
Given that if 3-ϕ induction motor is rotated in clockwise then the phase sequence of supply voltage is A-B-C. In counter clock wise rotation of the motor the phase sequence is change so in the counter clockwise rotation the phase sequence is A-C-B.

SOL 1.4.91 Option (A) is correct.
In linear electromagnetic circuit the field energy is equal to the co-energy.

$$W_f = W_f' = \frac{1}{2}Li^2 = \frac{1}{2}\psi_i = \frac{1}{2L}\psi^2$$

W_f = field energy
W_f' = co energy

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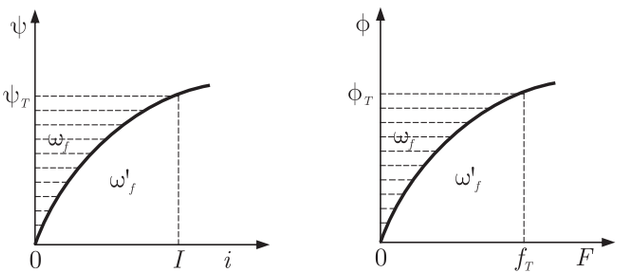

SOL 1.4.92 Option (A) is correct.
Given that
8-Pole, 50 Hz induction machine in seventh space harmonic mmf wave.
So,

Synchronous speed at 7^{th} harmonic is $= N_s/7$

$$\text{Speed of motor } N_s = \frac{120f}{P} = \frac{120 \times 50}{8} = 750 \text{ rpm}$$

$$\text{Synchronous speed is} = \frac{N_s}{7} = \frac{750}{7} = 107.14 \text{ rpm in forward direction}$$

SOL 1.4.93 Option (B) is correct.
Rotating electrical machines having its self inductance of stator and rotor windings is independent of the rotor position of synchronizing torque.
synchronizing torque

$$T_{\text{synchronizing}} = \frac{1}{\omega_s} m \frac{dP}{d\delta} \text{ Nm/elect. radian}$$

$$= \left(\frac{1}{\omega_s} m \frac{dP}{d\delta}\right)\frac{\pi P}{180} \text{ Nm/mech.degree}$$

SOL 1.4.94 Option (A) is correct.
Given that the armature of a permanent magnet dc motor is

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$$R_a = 0.8\,\Omega$$

At no load condition

$$V = 25\text{ V},\ I = 1.5\text{ A},\ N = 1500\text{ rpm}$$

$$\text{No load losses} = E \times I$$

$$\because\ E = V - IR_a$$

So

$$\text{No load losses} = (25 - 1.5 \times 0.8)1.5 = 35.7\text{ W}$$

At load condition

$$I = 3.5\text{ A}$$

$$\text{Iron losses} = I^2R = (3.5)^2 \times 0.8 = 9.8\text{ W}$$

$$\text{Total losses} = \text{No load losses} + \text{iron losses}$$

$$= 35.7 + 9.8 = 45.5\text{ W}$$

$$\text{Total power } P = VI$$

$$P = 25 \times 3.5$$

$$P = 87.5\text{ W}$$

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}$$

$$\eta = \frac{\text{total power} - \text{losses}}{\text{total power}}$$

$$= \frac{87.5 - 45.5}{87.5} \times 100 = 48.0\%$$

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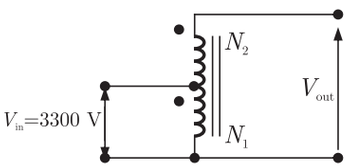
SOL 1.4.95 Option (D) is correct.

Given that 50 kVA, 3300/230 V, 1-ϕ transform



$$V_{\text{in}} = 3300\text{ V}$$

$$V_{\text{out}} = 3300 + 230 = 3530\text{ V}$$

Output current I_2 and output voltage 230 V

So

$$I_2 = \frac{50 \times 10^3}{230} = 217.4\text{ A}$$

When the output voltage is V_{out} then kVA rating of auto transformer will be

$$I_2 = 3530 \times 217.4$$

$$= 767.42\text{ kVA}$$

SOL 1.4.96 Option (D) is correct.

Given that 100 kVA, 11000/400 V, Delta-star distribution transformer resistance is 0.02 pu and reactance is 0.07 pu

So pu impedance $Z_{\text{pu}} = 0.02 + j0.07$

Base impedance referred to primary

$$Z_{\text{Base}} = \frac{V_P^2}{V_L I_L/3} = \frac{(11 \times 10^3)^2}{\frac{100 \times 10^3}{3}} = 3630\ \Omega$$

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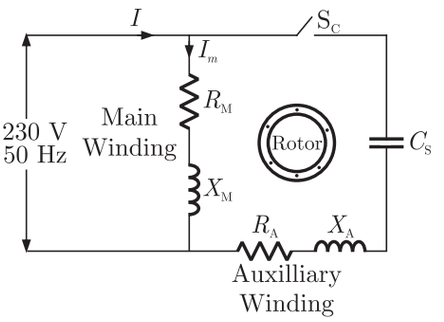
The phase impedance referred to primary

$$Z_{\text{primary}} = Z_{\text{pu}} \times Z_{\text{Base}}$$
$$= (0.02 + j0.07)(3630) = 72.6 + j254.1$$

SOL 1.4.97 Option (A) is correct.

Given that

230 V, 50 Hz, 4-Pole, capacitor-start induction motor



$$Z_m = R_m + X_m = 6.0 + j4.0\ \Omega$$
$$Z_A = R_A + X_A = 8.0 + j6.0\ \Omega$$

Phase angle of main winding

$$\angle I_m = \angle - Z_m = -\angle(6 + j4) = -\angle 33.7^\circ$$

So angle of the auxiliary winding when the capacitor is in series.

$$\angle I_A = -\angle(8 + j6) + \frac{1}{j\omega C}$$
$$= \angle(8 + j6) - \frac{j}{\omega C}$$
$$\alpha = \angle I_A - \angle I_m$$

So
$$90 = -\tan^{-1}\left[\left(6 - \frac{1}{\omega C}\right) - (-33.7)\right]$$
$$\frac{1}{\omega C} = 18 \qquad \omega = 2\pi f$$

So
$$C = \frac{1}{18 \times 2\pi f} = \frac{1}{18 \times 2 \times 3.14 \times 50}$$
$$= 176.8\ \mu\text{F}$$

SOL 1.4.98 Option (A) is correct.

Given that the armature has per phase synchronous reactance of 1.7 Ω and two alternator is connected in parallel

So,

both alternator voltage are in phase

So,

$$E_{f1} = \frac{3300}{\sqrt{3}}$$

$$E_{f2} = \frac{3200}{\sqrt{3}}$$

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Synchronizing current or circulating current

$$= \frac{E_C}{T_{S1} + T_{S2}}$$

Reactance of both alternator are same

So $$= \frac{E_{f1} - E_{f2}}{T_{S1} + T_{S2}} = \frac{1}{\sqrt{3}}\left(\frac{3300 - 3200}{1.7 + 1.7}\right) = 16.98 \text{ A}$$

SOL 1.4.99 Option (C) is correct.

Given $V = 400$ V, 15 kW power and $P = 4$

$$f = 50 \text{ Hz, Full load slip } (S) = 4\%$$

So $$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$\text{Actual speed} = \text{synchronous speed} - \text{slip}$$

$$N = 1500 - \frac{4}{100} \times 1500 = 1440 \text{ rpm}$$

Torque developed $T = \dfrac{P}{\omega_s(1-S)}$, where $\omega_s(1-S) = \dfrac{2\pi N}{60}$

$$= \frac{15 \times 10^3 \times 60}{2\pi \times 1440} = 99.47 \text{ Nm}$$

SOL 1.4.100 Option (B) is correct.

Given 1.8° angle, 2-ϕ Bipolar stepper motor and stepping rate is 100 step/second

So,

Step required for one revolution

$$= \frac{360}{1.8} = 200 \text{ steps}$$

$\because$ Time required for one revolution = 2 seconds

$$\text{rev/sec} = 0.5 \text{ rps}$$

and

$$\text{rev/min} = 30 \text{ rpm}$$

SOL 1.4.101 Option (C) is correct.

Given that:

$P = 8$ Pole, DC generator has wave-wound armature containing 32 coil of 6 turns each. Simplex wave wound flux per pole is 0.06 Wb

$$N = 250 \text{ rpm}$$

So,

Induced armature voltage

$$E_g = \frac{\phi Z N P}{60A}$$

$$Z = \text{total no.of armature conductor}$$

$$= 2CN_C = 2 \times 32 \times 6 = 384$$

$$E_g = \frac{0.06 \times 250 \times 3.84 \times 8}{60 \times 2}$$

$\because A = 2$ for wave winding

$$E_g = 384 \text{ volt}$$

SOL 1.4.102 Option (C) is correct.

Given a 400 V, 50 Hz and 0.8 p.f. loading delta connection 50 Hz synchronous

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machine, the reactance is 2 Ω. The friction and windage losses are 2 kW and core losses is 0.8 kW and shaft is supply 9 kW at a 0.8 loading power factor

So

$$\text{Input power} = 9\ \text{kW} + 2\ \text{kW} + 0.8\ \text{kW} = 11.8\ \text{kW}$$

$$\because \text{Input power} = \sqrt{3}\, V_2 I_2 = 11.8\ \text{kW}$$

$$I_2 = \frac{11.8\ \text{kW}}{\sqrt{3} \times 400 \times 0.8} = 21.29\ \text{A}$$

SOL 1.4.103 Option (B) is correct.

Given that 500 MW, 3-ϕ star connected synchronous generator has a rated voltage of 21.5 kV and 0.85 Power factor

So $$\sqrt{3}\, V_L I_L = 500\ \text{MW}$$

$$I_L = \frac{500 \times 10^6}{\sqrt{3} \times 21.5 \times 10^3 \times 0.85} = 15.79 \times 10^3$$

$$I_L = 15.79\ \text{kA}$$

SOL 1.4.104 Option (D) is correct.

Given that 1-ϕ transformer, maximum efficiency 90% at full load and unity power factor

So $$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + P_c} = \frac{(L.F)\cos\phi_2}{(L.F)\cos\phi_2 + P_{i(\text{Pu})} + P_c}$$

where $L.F.$ is the load fator.

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At full load, load factor is

$$L.F. = \sqrt{\frac{P_i}{P_c}} = 1$$

$$\cos\phi_2 = 1 \text{ at unity power factor}$$

so, $$90\% = \frac{1 \times 1}{1 + 2P_i}$$

$$P_i = 0.0555\ \text{MVA}$$

At half load, load factor is

$$\text{L.F} = \frac{1}{2} = .5$$

So, $$\eta = \frac{0.5 \times 1}{0.5 \times 0.0555 \times (0.5)^2 + 0.0555} \times 100$$

$$= 87.8\%$$

SOL 1.4.105 Option (C) is correct.

In food mixer the universal motor is used and in cassette tap recorder permanent magnet DC motor is used. The Domestic water pump used the single and three phase induction motor and escalator used the three phase induction motor.

SOL 1.4.106 Option (D) is correct.

Given a engine drive synchronous generator is feeding a partly inductive load. A capacitor is connected across the load to completely nullify the inductive current. Then the motor field current has to be reduced and fuel input left unaltered.

SOL 1.4.107 Option (A) is correct.

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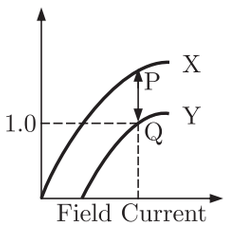
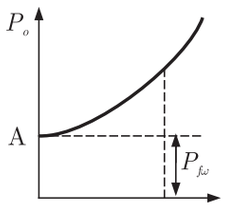


Given open circuit and full-load zero power factor of a synchronous generator. At point Q the zero power factor at 1.0 pu voltage. The voltage drop at point PQ is across synchronous reactance.

SOL 1.4.108 Option (D) is correct.

Given no load test on 3-ϕ induction motor, the graph between the input power and voltage drop is shown in figure, the intersection point yield the friction and windage loss.



Separation of fraction and windage loss

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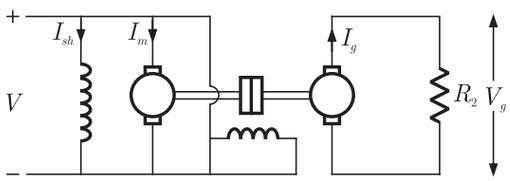
SOL 1.4.109 Option ( ) is correct.

SOL 1.4.110 Option (C) is correct.



Given that: The armature resistance in per unit is 0.2

so, $$R_a = 0.2$$

back emf equation of motor is

$$E_b = V - I_a R_a$$

given that no mechanical losses and armature reaction is neglected, so per unit value of emf induced by motor is

$$E_b = 0.98$$

The DC shunt motor is mechanically coupled by the generator so the emf induced by motor and generator is equal

$$E_g = E_b$$

so voltage generated by the generator is

$$V = 0.98 - 1 \times 0.2 = 0.96$$

per unit value of load resistance is equal to 0.96

SOL 1.4.111 Option (D) is correct.

Given that when the switch S_1 is closed and S_2 is open then the 11000 V is step down at 415 V output

Second time when the switch S_1 is open and switch S_2 is closed then 2-phase supply is connected to the transformer then the ratio of voltage is

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$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{11000}{415} = 26.50$$

The output terminal a and c are in opposite phase so cancelled with each other and terminal is equal to zero volt.

SOL 1.4.112 Option (D) is correct.

Given that

$$N_1 : N_2 : N_3 \text{ is } 4:2:1$$

Resistance $R = 10\ \Omega$

$$V_1 = 400\ \text{V}$$

so,

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{4}{2}$$

$$V_2 = \frac{2V_1}{4} = 200\ \text{V}$$

and

$$\frac{V_1}{V_3} = \frac{N_1}{N_3} = \frac{4}{1}$$

$$V_3 = 100\ \text{V}$$

so current in secondary winding

$$I_2 = \frac{V_2}{R} = \frac{200}{10} = 20\ \text{A}$$

The current in third winding when the capacitor is connected

so $$I_3 = \frac{V_3}{-jX_c} = \frac{100}{-j2.5} = j40$$

When the secondary winding current I_2 is referred to primary side i.e $I_1^{'}$

So

$$\frac{I_1^{'}}{I_2} = \frac{N_2}{N_1} = \frac{2}{4}$$

$$I_1^{'} = \frac{20}{2} = 10\ \text{A}$$

and winding third current I_3 is referred to Primary side i.e $I_1^{''}$. I_3 flows to opposite to I_1

So

$$\frac{I_1^{''}}{-I_3} = \frac{N_3}{N_1} = \frac{1}{4}$$

$$I_1^{''} = -j10$$

So total current in primary winding is

$$I_1 = I_1^{''} + I_2^{''} = 10 - j10\ \text{A}$$

SOL 1.4.113 Option (A) is correct.

Given that:

P Stator winding current is dc, rotor winding current is ac

Q Stator winding current is ac, rotor winding current is dc

R Stator winding current is ac, rotor winding current is ac

S Stator has salient pole and rotor has commutator

T Rotor has salient pole and slip rings and stator is cylindrical

U Both stator and rotor have poly-phase windings

So

DC motor/machines:

The stator winding is connected to dc supply and rotor winding flows ac current. Stator is made of salient pole and Commutator is connected to the rotor so rotor

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winding is supply ac power.

Induction machines:
In induction motor the ac supply is connected to stator winding and rotor and stator are made of poly-phase windings.

Synchronous machines:
In this type machines the stator is connected to ac supply but rotor winding is excited by dc supply. The rotor is made of both salient pole and slip rings and stator is made of cylindrical.

SOL 1.4.114 Option (C) is correct.
Given that
F_s is the peak value of stator mmf axis. F_r is the peak value of rotor mmf axis. The rotor mmf lags stator mmf by space angle δ. The direction of torque acting on the rotor is clockwise or counter clockwise.
When the opposite pole is produced in same half portion of stator and rotor then the rotor moves. So portion of stator is north-pole in ABC and rotor abc is produced south pole as well as portion surface CDA is produced south pole and the rotor cda is produced North pole.
The torque direction of the rotor is clock wise and torque at surface is in counter clockwise direction.

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SOL 1.4.115 Option (A) is correct.
Given that:
A 4-pole, 3-ϕ, double layer winding has 36 slots stator with 60° phase spread, coil span is 7 short pitched
so,

$$\text{Pole pitch} = \frac{\text{slot}}{\text{pole}} = \frac{36}{4} = 9$$

$$\text{Slot/pole/phase} = 3$$

so, 3-slots in one phase, if it is chorded by 2 slots then

$$\text{Out of } 3 \rightarrow 2 \text{ have different phase}$$

$$\text{Out of } 36 \rightarrow 24 \text{ have different phase.}$$

SOL 1.4.116 Option (B) is correct.
Given that:
3-ϕ induction motor is driving a constant load torque at rated voltage and frequency. Voltage and frequency are halved and stator resistance, leakage reactance and core losses are ignored.
Then the motor synchronous speed and actual speed difference are same.

$$N_s = \frac{120f}{P}$$

The leakage reactance are ignored then the air gap flux remains same and the stator resistance are ignored then the stator current remain same.

SOL 1.4.117 Option (D) is correct.
Given that: 1-ϕ induction motor main winding excited then the rotating field of motor changes, the forward rotating field of motor is greater then the back ward rotating field.

SOL 1.4.118 Option (B) is correct.

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Given that:

A dc series motor driving a constant power load running at rated speed and rated voltage. It's speed brought down 0.25 pu. Then

Emf equation of dc series motor

$$E = V - (R_a + R_{se})$$

$$R_a + R_{se} = R$$

so, $$E = V - IR = K\phi N$$

then $$N = \frac{E}{K\phi}$$

In series motor $\phi \alpha I$

so, $$N = \frac{V - IR}{KI}$$

At constant power load

$$E \times I = T \times W = \text{Const} \quad ...(1)$$

$$T = K\phi I = KI^2 \quad ...(2)$$

If W is decreased then torque increases to maintain power constant.

$$T \propto I^2$$

$$W = \frac{1}{4} \text{ then } T = 4$$

So current is increased 2 time and voltage brought down to 0.5 pu.

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SOL 1.4.119 Option (A) is correct.

Given 400 V, 50 Hz, Y-connected, 3-ϕ squirrel cage induction motor operated from 400 V, 75 Hz supply. Than Torque is decreased.

$\because$ Machine is rated at 400 V, 50 Hz

and it is operated from 400 V, 75 Hz

so, speed of Motor will increase as $N = \frac{120f}{P} \Rightarrow N \propto f$

and we know Torque in induction motor

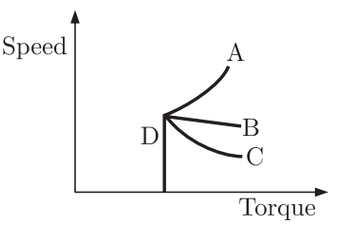
$$T_e = \frac{3}{W_s} I_2^2 \frac{R_2}{S} \Rightarrow T_e \propto \frac{1}{N}$$

If speed increases, torque decreases.

SOL 1.4.120 Option (B) is correct.

Motor is overloaded, and magnetic circuit is saturated. Than Torque speed characteristics become linear at saturated region.

as shown in figure



actual torque-speed characteristics is given by curve B.

SOL 1.4.121 Option (D) is correct.

Given that transformer rating 1 kVA, 230 V/100 V, 1-ϕ, 50 Hz, operated at 250 V, 50 Hz at high voltage winding and resistive load at low voltage winding which draws rated current, than current drawn from the source will not be

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sinusoidal.

SOL 1.4.122 Option (A) is correct.
In this case voltmeter reading will be zero.

SOL 1.4.123 Option ( ) is correct.

SOL 1.4.124 Option (C) is correct.
Slip ring induction motor of 5 kW, 400 V, 50 Hz.

rotor = 6 Poles, stator= 4 Poles

than speed of motor = ?

speed = 0

$\because$ No. of rotor poles $\neq$ No. of stator poles
so motor will not rotate.

SOL 1.4.125 Option (B) is correct.
Flux per pole in synchronous motor when stator disconnected from supply is = 25 MWb
When stator connected to rated supply than flux per pole is = 20 MWb
As in first case stator is disconnected from supply.

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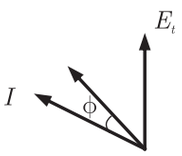
Second case when stator connected to rated supply then terminal voltage decreases and current will lead from the supply voltage.



SOL 1.4.126 Option ( ) is correct.
Given: Separately Excited *dc* motor of 230 V, 250 rpm, 100 A

$$r_a = 0.5\ \Omega$$

It is driving a load.Torque speed characteristics as given below

$$T_L = 500 - 10\omega$$

Steady state speed = ?

Back emf of motor $E_b = V - I_a R_a = 230 - 100(0 - 5) = 180$ V

Torque is given as $T_e = \frac{E_b I_a}{\omega} = \frac{180 \times 100 \times 60}{250 \times 2 \times 3.14} = 687.54$ Nm

Now given that $T_L = 500 - 10\omega$

$$\omega = \frac{500 - T_L}{10} = \frac{500 - 687.54}{10} = -18.754 \text{ rad/sec}$$

$$N = \frac{-18.756 \times 60}{2\pi} = -179.08 \text{ rpm}$$

$-$ve sign employs that rotor direction is opposite to that of generator.

SOL 1.4.127 *

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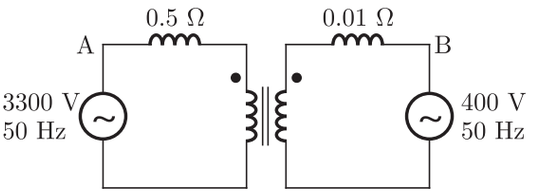
Given

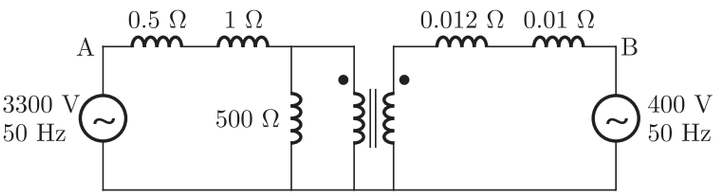


X_m referred to high voltage $X_m = 500\ \Omega$

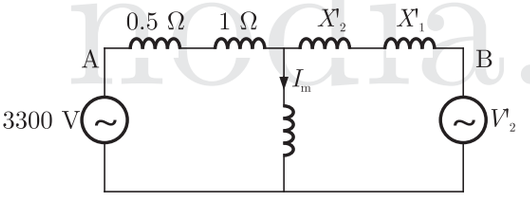
$X_{l1} = 1.0\ \Omega, X_{l2} = 0.012\ \Omega$ (Leakage reactance of high voltage and low voltage)

Magnetising $A_T = ?$

First we have to draw its equivalent circuit as



now equivalent circuit referred to high voltage side is as



$$X'_2 = \left(\frac{99}{12}\right)^2 \times 0.012 = 0.8167$$

$$X'_1 = \left(\frac{99}{12}\right)^2 \times 0.01 = 0.68$$

$$V'_2 = \left(\frac{99}{12}\right) \times 400 = 3300\ \text{V}$$

now magnetizing current

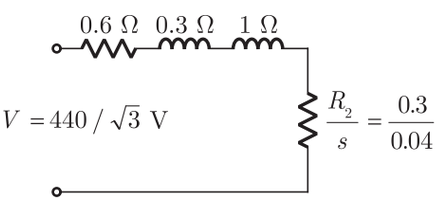
$$I_m = \frac{3300}{0.5 + 1.0 + 500} + \frac{3300}{0.8167 + 0.68 + 500} = 13.1605\ \text{Amp}$$

magnetizing ampere turns

$$A_T = 13.1605 \times 99 = 1302.84\ \text{Ampereturns}$$

SOL 1.4.128 Option ( ) is correct.

Equivalent circuit of induction motor referred to stator side



$$N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000\ \text{rpm}$$

$$\text{slip} = \frac{N_s - N_r}{N_s} = \frac{1000 - 960}{1000} = 0.04$$

Current $I = \dfrac{V}{\sqrt{\left(R_s + \dfrac{R'_r}{s}\right)^2 + (X_s + X'_r)^2}}$

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$$= \frac{440}{\sqrt{3}\sqrt{\left(0.6+\frac{0.3}{0.04}\right)^2+(1+1)^2}} = 30.447 \text{ Amp}$$

$$\text{Torque } T_e = \frac{3}{\omega_s} I_2^2 \left(\frac{r}{s}\right)$$

$$T_e = \frac{3 \times 60}{2\pi \times 1000} \times (30.447)^2 \times \frac{0.3}{0.04} = 199.18 \text{ N-m}$$

If it will work as generator than slip will be negative

$$S = \frac{N_s - N_e}{N_s}$$

$$-0.4 = \frac{1000 - N_r}{1000}$$

$$N_r = 1040 \text{ rpm}$$

SOL 1.4.129 Option ( ) is correct.

Given 415 V, 2-Pole, 3-ϕ, 50 Hz, Y-connected synchronous motor

$X_s = 2\ \Omega$ per phase $I = 20$ A at 4 PF

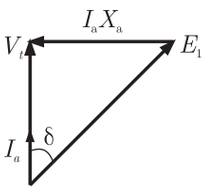
Mechanical load is increased till $I = 50$ A

Then

(a) Per phase open circuit voltage $E_0 = ?$

(b) Developed power $= ?$

In first case the UPF phasor diagram is being drawn as



from phasor diagram $E_0^2 = V_t^2 + I_a^2 \times s^2$

$$= \left(\frac{415}{\sqrt{3}}\right)^2 + 20^2 \times 2^2 = 242.91 \text{ V}$$

now I_a is increased than load angle and power factor angle is also increased as ($E_0 =$ constant)

Than $(I_a \times X_s)^2 = E_0^2 + V_t^2 - 2E_0^2 V_t \cos\delta$

$$(50 \times 2)^2 = (242.91)^2 + \left(\frac{415}{\sqrt{3}}\right)^2 - 2 \times \frac{242.91}{\sqrt{3}} \times 415 \cos\delta$$

$$\cos\delta = \frac{(242.91)^2 + (239.6)^2 - (100)^2}{2 \times 242.91 \times 239.6}$$

$$\cos\delta = 0.914 \Rightarrow \delta = 23.90^\circ$$

$$\text{Power } P_i = \frac{E_0 V_t \sin\delta}{X} = \frac{242.91 \times 239.6}{2} \sin 23.9 = 11789.87$$

$$P_i = VI\cos\theta = 11789.87$$

$$239.6 \times 50 \cos\theta = 11789.87$$

$$\cos\theta = 9841$$

$$\text{Power developed} = 3(P - I^2 R) = 3(11789.87 - 50^2 \times 2) = 35369.61 \text{ W}$$

SOL 1.4.130 Option (A) is correct.

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We know that in case of practical transformer with resistive load, the core flux is strictly constant with variation of load.

SOL 1.4.131 Option (A) is correct.

In synchronous machine it is known that

$$X_d > X'_d > X''_d$$

where X_d = steady state d-axis reactance

X'_d = transient d-axis reactance

X''_d = sub-transient d-axis reactance

SOL 1.4.132 Option (B) is correct.

50 Hz, balanced 3-ϕ, Y-connected supply is given to Y-load instantaneous phase-a of supply is $V\cos\omega t$ and load current is$I\cos(\omega t-\phi)$ then 3-ϕ instantaneous power = ?

$$\begin{aligned}P &= \text{sum of individual power of all phases}\\ &= V_1I_1+V_2I_2+V_3I_3\\ &= V\cos\omega t\left[I\cos(\omega t-\phi)\right]+V\cos(\omega t-120^\circ)I\cos(\omega t-\phi-120^\circ)\\ &\qquad +V\cos(\omega t+120^\circ)I\cos(\omega t+120^\circ-\phi)\\ &= \frac{VI}{2}[\cos(2\omega t-\phi)+\cos\phi+\cos(2\omega t-240^\circ-\phi)+\cos\phi\\ &\qquad +\cos(2\omega t+240^\circ-\phi+\cos\phi)]\end{aligned}$$

or $$\begin{aligned}P &= \frac{VI}{2}[\cos(2\omega t-\phi)+3\cos\phi+\cos(2\omega t-\phi)\cos240^\circ\\ &\quad -\sin(2\omega t-\phi)\sin240^\circ+\cos(2\omega t-\phi)\cos240^\circ+\sin(2\omega t-\phi)\sin240^\circ]\\ P &= \frac{VI}{2}[\cos(2\omega t-\phi)+3\cos\phi-\cos(2\omega t-\phi)] = \frac{3VI}{2}\cos\phi\end{aligned}$$

Hence power is constant.

SOL 1.4.133 Option (A) is correct.

In transformer protection, harmonic restraint is used to guard against "Magnetizing inroush current".

SOL 1.4.134 Option (C) is correct.

For armature controlled separately excited dc motor drive with closed loop speed control. We use inner current loop because inner current loop limits the peak current of motor to the permissible value.

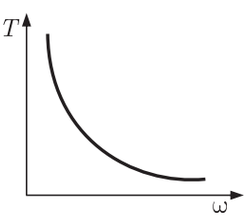
SOL 1.4.135 Option (D) is correct.

$\because$ Output of motor $= E_aI_a =$ constant

also power output $P_{o/p} = T\omega$

so $T\omega =$ costant

or $$T \propto \frac{1}{\omega}$$



So torque speed characteristics is a rectangular hyperbola.

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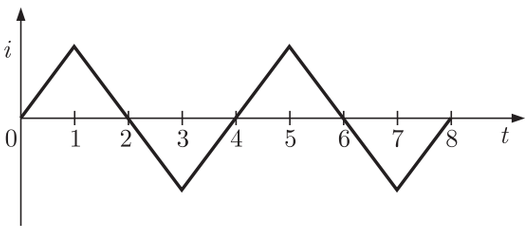
SOL 1.4.136 Option ( ) is correct.

Ideal transformer of linear B-H with turn ratio 1:1



(a) The flux ϕ_{oc}, when secondary is open

$\phi_{oc} \propto I$

so, it is same as current wave form.

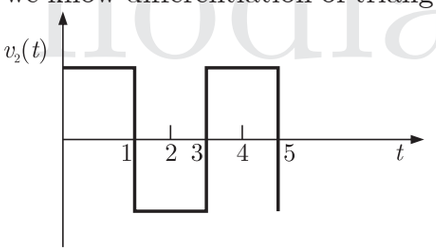
(b) Secondary open circuited terminal voltage : $v_2(t) = ?$

$$\text{we know } e_1 = -\frac{d\phi_{oc}}{dt}$$

and $$\frac{e_1}{e_2} = \frac{N_1}{N_2} = 1$$

So $$v_2(t) = e_2 = -\frac{d}{dt}(\phi_{oc}) \ (\because \text{secondary open circuited})$$

we know differentiation of triangular wave form is square. so waveform is given as

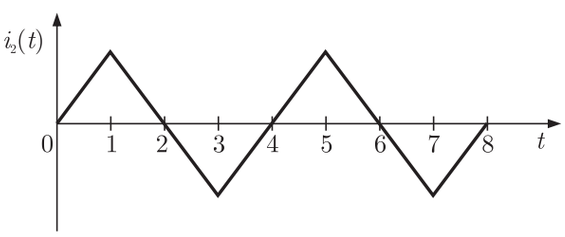


(c) Short circuited secondary current $[i_2(t)]$

$$\frac{i_1(t)}{i_2(t)} = \frac{N_2}{N_1} = 1$$

so $$i_2(t) = i_1(t)$$

It is same as primary current which is



(d) Short circuited secondary core flux.

$$\phi_{sc}(t) = ?$$

we know $$\phi_{sc}(t) \propto i_2(t)$$

so, it is same waveform as short circuit current in secondary.

SOL 1.4.137 *Option (B) is correct.

Given data

In dc motor $N = 2000$ rpm, $W_h = 500$ W, $W_e = 200$ W, $\phi =$ constant

N_1 os the speed at which is iron losses W_i is halved.

we know hysteresis loss $W_h = k_h f B_m$

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and eddy current loss $W_e = k_e f^2 B_m$

$\because$ flux is constant so speed $\propto$ Frequency

again $W_h = k_1 N \Rightarrow 500 = k_1 \times 2000 \Rightarrow k_1 = \frac{1}{4}$

$$W_e = k_2 N^2 \Rightarrow 200 = k_2 (2000)^2 \Rightarrow k_2 = 5 \times 10^{-5}$$

We know that iron loss $W_i = W_n + W_e$

$$\frac{W_i}{2} = k_1 N_1 + k_2 N_1^2$$

$$350 = \frac{1}{4} N_1 + 5 \times 10^{-5} N_1^2$$

or $20 \times 10^{-5} N_1^2 + N_1 - 1400 = 0$

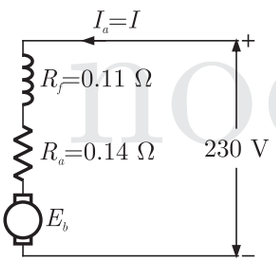
$N_1 = 623$ rpm, -1072.25 rpm

as $N_1 = -1072.25$ is not possible

so, $N_1 = 623$ rpm

SOL 1.4.138 *Option (B) is correct.

Given



rated

$$N = 1000 \text{ rpm}$$

$$I_a = 80 \text{ A}$$

ϕ at $I_a = 20$ A is 0.4 times of rated.

we have to calucalte speed at $I_a^{'} = 20$ A

we know in case of series motor

$$N \propto E_b/\phi$$

$$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{\phi_2}{\phi_1}$$

$$E_{b1} = V - I_a(R_a + R_f)$$

$$= 230 - 80(0.14 + 0.11) = 210 \text{ V}$$

$$N_1 = 1000 \text{ rpm}$$

$$E_{b2} = V - I_a^{'}(R_a + R_f) = 230 - 20(0.25) = 225 \text{ V}$$

$$N_2 = ?$$

$$\phi_2 = 0.4\phi_1$$

$$\frac{1000}{N_2} = \frac{210}{225} \times \frac{0.4\phi_1}{\phi_1}$$

$$N_2 = 1000 \times \frac{225}{210} \times \frac{1}{0.4}$$

$$N_2 = 2678.57 \text{ rpm}$$

SOL 1.4.139 *Option ( ) is correct.

Given 50 kW of synchronous motor driven by another motor.

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excitation is off than driven motor takes 800 W of power
when armature is short circuited and rated $I_a = 10$ A, than it takes 2500 W
Open circuited armature takes $W_1 = 1800$ W
η of motor at 50 % load, neglecting losses of motor.
$\because$ excitation is off there is friction losses $W_f = 800$ W
short circuit loss

$$W_s = W_i - W_f = 2500 - 800 = 1700 \text{ W}$$

open circuit loss

$$W_0 = W_1 - W_f = 1800 - 800 = 1000 \text{ W}$$

$$\text{Total loss} = 800 + 1700 + 1000 = 3500 \text{ W}$$

at 50% load, output= 25 kW

$$\eta = \left(1 - \frac{\text{losses}}{\text{input}}\right)100$$

$$= 1 - \frac{3500}{25 \times 10^3 + 3500}$$

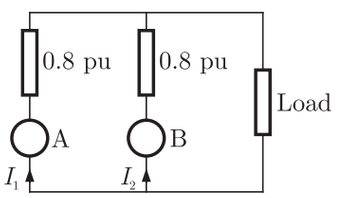
$$= 87.71\%$$

SOL 1.4.140 * Option ( ) is correct.
Given Two identical Generator each of 100 MVA in parallel

$$P = 100 \text{ MW at, p.f.} = 0.8 \text{ lagging}$$

Equal load sharing at initial.
If I_{f1} = reduced by 5% and I_{f2} = increased by 5%
Then load sharing of generator = ?

$$X_d = X_a = 0.8 \text{ Pu}$$



Case I
Load sharing of each generator equal i.e 50 MW at 0.8 p.f. lagging
i.e 40 MW and 30 MVAR

$$V = I = 1 \text{ Pu}$$

Back emf of generators

$$E_{A1} = E_{B1} = V + IX_d \sin\phi$$

$$= 1 + 1 \times 0.8 \times 0.6 = 1.48 \text{ Pu}$$

Case II
Now in first generator field in decreased by 5% i.e

$$E_{A2} = 0.95(E_{A1}) = 0.95 \times 1.48 = 1.40 \text{ Pu}$$

And in second generator field is increased by 5% i.e

$$E_{B2} = 1.05, \quad E_{B1} = 1.05 \times 1.48 = 1.554 \text{ Pu}$$

In this case I_1 and I_2 are being given by as

$$I_1 = \frac{1.4 - 1}{0.48} = 0.846 \text{ Pu}$$

$$I_2 = \frac{1.554 - 1}{0.48} = 1.154 \text{ Pu}$$

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so $P_A = 1 \times 0.846 = 0.846$ Pu

$P_B = 1 \times 1.154 = 1.154$ Pu

Load sharing in MW by generator $1 = 0.846 \times 40 = 33.84$ MW

by generator $2 = 1.154 \times 40 = 46.16$ MW

MVAR load sharing by generator $1 = 0.846 \times 30 = 25.38$ MVAR

MVAR load sharing by generator $2 = 1.154 \times 30 = 34.62$ MVAR

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5

POWER SYSTEMS

YEAR 2013 TWO MARKS

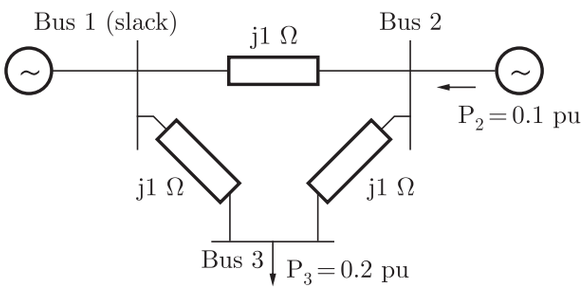
MCQ 1.5.1 For a power system network with n nodes, Z_{33} of its bus impedance matrix is $j0.5$ per unit. The voltage at node 3 is $1.3\angle -10^\circ$ per unit. If a capacitor having reactance of $-j3.5$ per unit is now added to the network between node 3 and the reference node, the current drawn by the capacitor per unit is

(A) $0.325\angle -100^\circ$ (B) $0.325\angle 80^\circ$

(C) $0.371\angle -100^\circ$ (D) $0.433\angle 80^\circ$

Statement for Linked Answer Questions: 2 & 3

In the following network, the voltage magnitudes at all buses are equal to 1 pu, the voltage phase angles are very small, and the line resistances are negligible. All the line reactances are equal to $j1\,\Omega$



MCQ 1.5.2 The voltage phase angles in rad at buses 2 and 3 are

(A) $\theta_2 = -0.1,\ \theta_3 = -0.2$ (B) $\theta_2 = 0,\ \theta_3 = -0.1$

(C) $\theta_2 = 0.1,\ \theta_3 = 0.1$ (D) $\theta_2 = 0.1,\ \theta_3 = 0.2$

MCQ 1.5.3 If the base impedance and the line-to line base voltage are 100 ohms and 100 kV respectively, then the real power in MW delivered by the generator connected at the slack bus is

(A) -10 (B) 0

(C) 10 (D) 20

YEAR 2012 ONE MARK

MCQ 1.5.4 The bus admittance matrix of a three-bus three-line system is

$$Y = j\begin{bmatrix} -13 & 10 & 5 \\ 10 & -18 & 10 \\ 5 & 10 & -13 \end{bmatrix}$$

If each transmission line between the two buses is represented by an equivalent π-network, the magnitude of the shunt susceptance of the line connecting bus 1 and 2 is

(A) 4 (B) 2

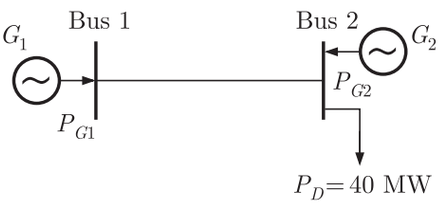
(C) 1 (D) 0

MCQ 1.5.5 A two-phase load draws the following phase currents : $i_1(t) = I_m \sin(\omega t - \phi_1)$, $i_2(t) = I_m \cos(\omega t - \phi_2)$. These currents are balanced if ϕ_1 is equal to.

(A) $-\phi_2$ (B) ϕ_2

(C) $(\pi/2 - \phi_2)$ (D) $(\pi/2 + \phi_2)$

MCQ 1.5.6 The figure shows a two-generator system applying a load of $P_D = 40\,\text{MW}$, connected at bus 2.



The fuel cost of generators G_1 and G_2 are :
$C_1(P_{G1}) = 10000\,\text{Rs/MWh}$ and $C_2(P_{G2}) = 12500\,\text{Rs/MWh}$ and the loss in the line is $P_{loss(pu)} = 0.5P^2_{G1(pu)}$, where the loss coefficient is specified in pu on a 100 MVA base. The most economic power generation schedule in MW is

(A) $P_{G1} = 20, P_{G2} = 22$ (B) $P_{G1} = 22, P_{G2} = 20$

(C) $P_{G1} = 20, P_{G2} = 20$ (D) $P_{G1} = 0, P_{G2} = 40$

MCQ 1.5.7 The sequence components of the fault current are as follows : $I_{\text{positive}} = j1.5\,\text{pu}$, $I_{\text{negative}} = -j0.5\,\text{pu}$, $I_{\text{zero}} = -j1\,\text{pu}$. The type of fault in the system is

(A) LG (B) LL

(C) LLG (D) $LLLG$

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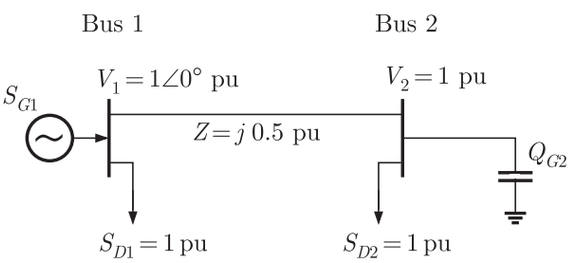
MCQ 1.5.8 For the system below, S_{D1} and S_{D2} are complex power demands at bus 1 and bus 2 respectively. If $|V_2| = 1\,\text{pu}$, the VAR rating of the capacitor (Q_{G2}) connected at bus 2 is



(A) 0.2 pu (B) 0.268 pu

(C) 0.312 pu (D) 0.4 pu

MCQ 1.5.9 A cylinder rotor generator delivers 0.5 pu power in the steady-state to an infinite bus through a transmission line of reactance 0.5 pu. The generator no-load voltage is 1.5 pu and the infinite bus voltage is 1 pu. The inertia constant of the generator is 5 MW-s/MVA and the generator reactance is 1 pu. The critical clearing angle, in degrees, for a three-phase dead short circuit fault at the generator terminal is

(A) 53.5 (B) 60.2

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(C) 70.8 (D) 79.6

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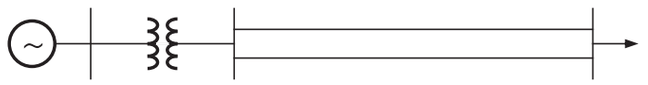
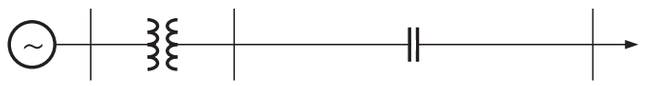
MCQ 1.5.10 A nuclear power station of 500 MW capacity is located at 300 km away from a load center. Select the most suitable power evacuation transmission configuration among the following options

(A)



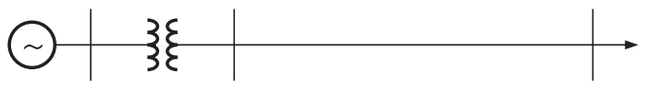
132 kV, 300 km double circuit

(B)



132 kV, 300 km single circuit with 40% series capacitor compensation

(C)



400 kV, 300 km single circuit

(D)

400 kV, 300 km double circuit

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MCQ 1.5.11 A negative sequence relay is commonly used to protect

(A) an alternator (B) an transformer

(C) a transmission line (D) a bus bar

MCQ 1.5.12 For enhancing the power transmission in along EHV transmission line, the most preferred method is to connect a

(A) Series inductive compensator in the line

(B) Shunt inductive compensator at the receiving end

(C) Series capacitive compensator in the line

(D) Shunt capacitive compensator at the sending end

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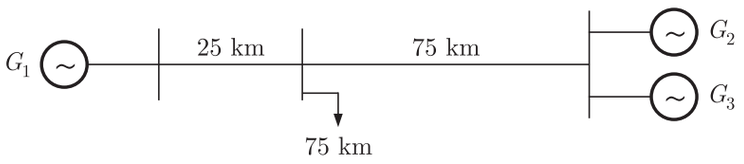
MCQ 1.5.13 A load center of 120 MW derives power from two power stations connected by 220 kV transmission lines of 25 km and 75 km as shown in the figure below. The three generators G_1, G_2 and G_3 are of 100 MW capacity each and have identical fuel cost characteristics. The minimum loss generation schedule for supplying the 120 MW load is



(A) $P_1 = 80\,\text{MW} + \text{losses}$, $P_2 = 20\,\text{MW}$, $P_3 = 20\,\text{MW}$

(B) $P_1 = 60\,\text{MW}$, $P_2 = 30\,\text{MW} + \text{losses}$, $P_3 = 30\,\text{MW}$

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$P_1 = 40\,\text{MW}$
$P_2 = 40\,\text{MW}$
$P_3 = 40\,\text{MW} + \text{losses}$

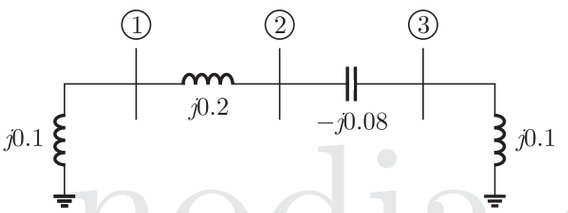
(D) $P_1 = 30\,\text{MW} + \text{losses}$
$P_2 = 45\,\text{MW}$
$P_3 = 45\,\text{MW}$

MCQ 1.5.14 The direct axis and quadrature axis reactances of a salient pole alternator are 1.2 p.u and 1.0 p.u respectively. The armature resistance is negligible. If this alternator is delivering rated kVA at upf and at rated voltage then its power angle is

(A) 30° (B) 45°

(C) 60° (D) 90°

MCQ 1.5.15 A three – bus network is shown in the figure below indicating the p.u. impedance of each element.



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The bus admittance matrix, Y-bus, of the network is

(A) $j\begin{bmatrix} 0.3 & -0.2 & 0 \\ -0.2 & 0.12 & 0.08 \\ 0 & 0.08 & 0.02 \end{bmatrix}$

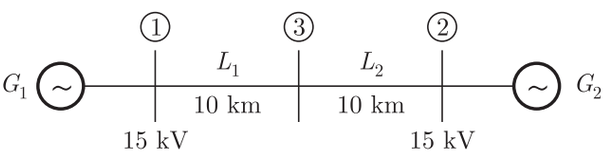
(B) $j\begin{bmatrix} -15 & 5 & 0 \\ 5 & 7.5 & -12.5 \\ 0 & -12.5 & 2.5 \end{bmatrix}$

(C) $j\begin{bmatrix} 0.1 & 0.2 & 0 \\ 0.2 & 0.12 & -0.08 \\ 0 & -0.08 & 0.10 \end{bmatrix}$

(D) $j\begin{bmatrix} -10 & 5 & 0 \\ 5 & 7.5 & 12.5 \\ 0 & 12.5 & -10 \end{bmatrix}$

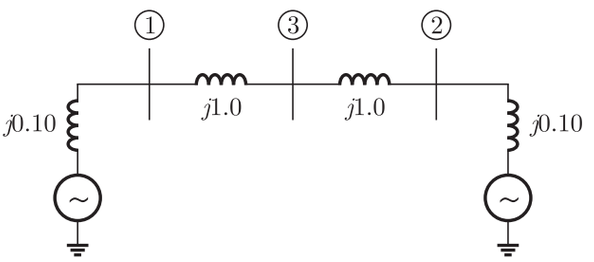
Statement For Linked Answer Questions : 13 & 14.

MCQ 1.5.16 Two generator units G_1 and G_2 are connected by 15 kV line with a bus at the mid-point as shown below



$G_1 = 250\,\text{MVA}$, 15 kV, positive sequence reactance $X_{G_1} = 25\%$ on its own base
$G_2 = 100\,\text{MVA}$, 15 kV, positive sequence reactance $X_{G_2} = 10\%$ on its own base L_1 and $L_2 = 10\,\text{km}$, positive sequence reactance $X_L = 0.225\,\Omega/\text{km}$

(A)



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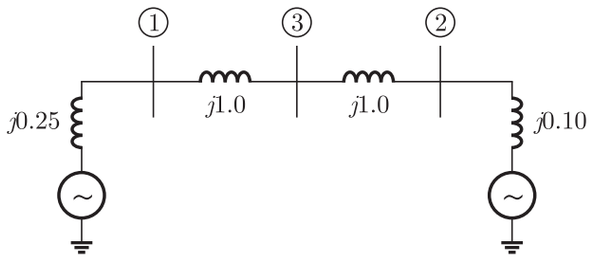
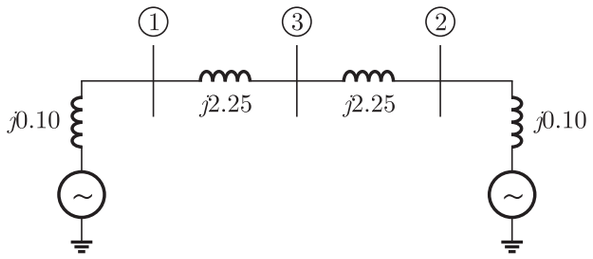
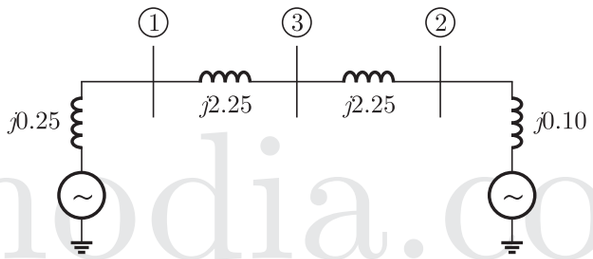
(B)



(C)



(D)



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MCQ 1.5.17 In the above system, the three-phase fault MVA at the bus 3 is

(A) 82.55 MVA (B) 85.11 MVA

(C) 170.91 MVA (D) 181.82 MVA

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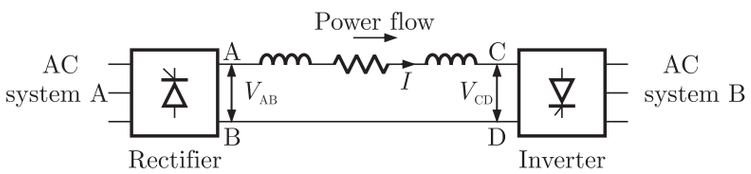
MCQ 1.5.18 Power is transferred from system A to system B by an HVDC link as shown in the figure. If the voltage V_{AB} and V_{CD} are as indicated in figure, and $I > 0$, then



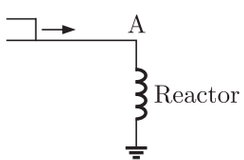
(A) $V_{AB} < 0, V_{CD} < 0, V_{AB} > V_{CD}$

(B) $V_{AB} > 0, V_{CD} > 0, V_{AB} < V_{CD}$

(C) $V_{AB} > 0, V_{CD} > 0, V_{AB} > V_{CD}$

(D) $V_{AB} > 0, V_{CD} < 0$

MCQ 1.5.19 Consider a step voltage of magnitude 1 pu travelling along a lossless transmission line that terminates in a reactor. The voltage magnitude across the reactor at the instant travelling wave reaches the reactor is



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(A) -1 pu (B) 1 pu

(C) 2 pu (D) 3 pu

MCQ 1.5.20 Consider two buses connected by an impedence of $(0+5j)\,\Omega$. The bus '1' voltage is $100\angle 30^\circ$ V, and bus '2' voltage is $100\angle 0^\circ$ V. The real and reactive power supplied by bus '1' respectively are

(A) 1000 W, 268 VAr (B) -1000 W, -134 VAr

(C) 276.9 W, -56.7 VAr (D) -276.9 W, 56.7 VAr

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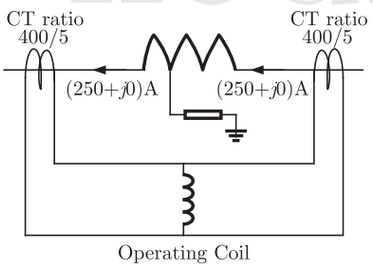
MCQ 1.5.21 A three-phase, 33 kV oil circuit breaker is rated 1200 A, 2000 MVA, 3 s. The symmetrical breaking current is

(A) 1200 A (B) 3600 A

(C) 35 kA (D) 104.8 kA

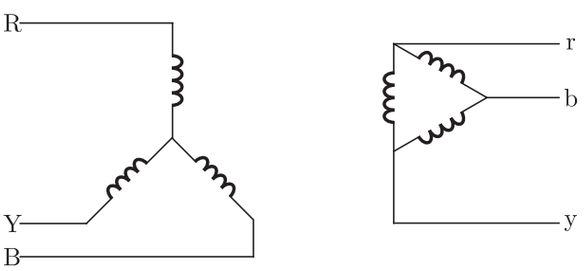
MCQ 1.5.22 Consider a stator winding of an alternator with an internal high-resistance ground fault. The currents under the fault condition are as shown in the figure The winding is protected using a differential current scheme with current transformers of ratio 400/5 A as shown. The current through the operating coils is

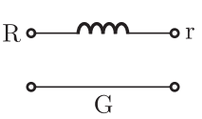


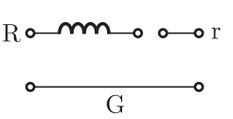
(A) 0.1875 A (B) 0.2 A

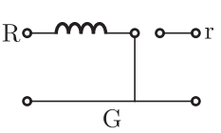
(C) 0.375 A (D) 60 kA

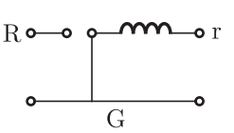
MCQ 1.5.23 The zero-sequence circuit of the three phase transformer shown in the figure is



(A) 

(B) 

(C) 

(D) 

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MCQ 1.5.24 A 50 Hz synchronous generator is initially connected to a long lossless transmission line which is open circuited at the receiving end. With the field voltage held constant, the generator is disconnected from the transmission line. Which of the following may be said about the steady state terminal voltage and field current of the generator ?

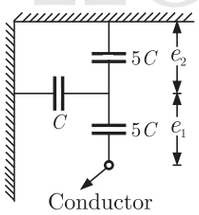
(A) The magnitude of terminal voltage decreases, and the field current does not change.

(B) The magnitude of terminal voltage increases, and the field current does not change.

(C) The magnitude of terminal voltage increases, and the field current increases

(D) The magnitude of terminal voltage does not change and the field current decreases.

MCQ 1.5.25 Consider a three-phase, 50 Hz, 11 kV distribution system. Each of the conductors is suspended by an insulator string having two identical porcelain insulators. The self capacitance of the insulator is 5 times the shunt capacitance between the link and the ground, as shown in the figures. The voltages across the two insulators are



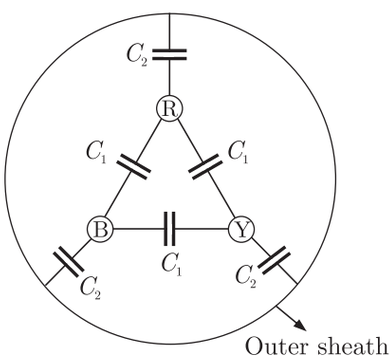
(A) $e_1 = 3.74$ kV, $e_2 = 2.61$ kV

(B) $e_1 = 3.46$ kV, $e_2 = 2.89$ kV

(C) $e_1 = 6.0$ kV, $e_2 = 4.23$ kV

(D) $e_1 = 5.5$ kV, $e_2 = 5.5$ kV

MCQ 1.5.26 Consider a three-core, three-phase, 50 Hz, 11 kV cable whose conductors are denoted as R, Y and B in the figure. The inter-phase capacitance(C_1) between each line conductor and the sheath is $0.4\,\mu$F . The per-phase charging current is



(A) 2.0 A

(B) 2.4 A

(C) 2.7 A

(D) 3.5 A

MCQ 1.5.27 For the power system shown in the figure below, the specifications of the components are the following :

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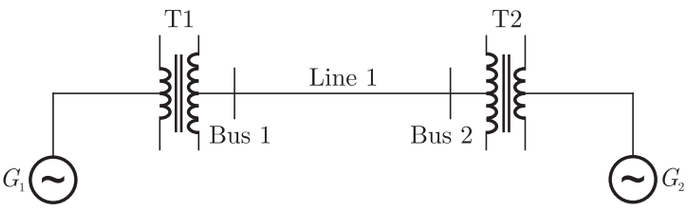
G_1: 25 kV, 100 MVA, $X = 9\%$

G_2: 25 kV, 100 MVA, $X = 9\%$

T_1: 25 kV/220 kV, 90 MVA, $X = 12\%$

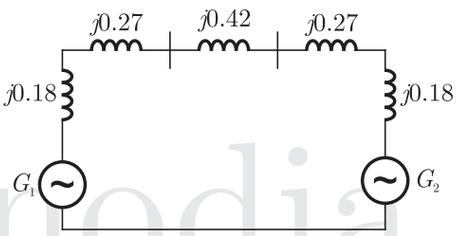
T_2: 220 kV/25 kV, 90 MVA, $X = 12\%$

Line 1: 200 kV, $X = 150$ ohms



Choose 25 kV as the base voltage at the generator G_1, and 200 MVA as the MVA base. The impedance diagram is

(A)



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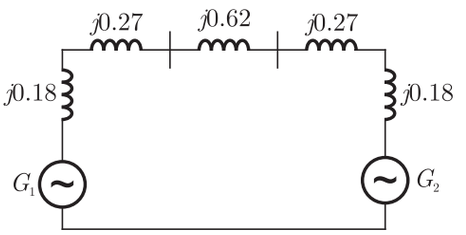
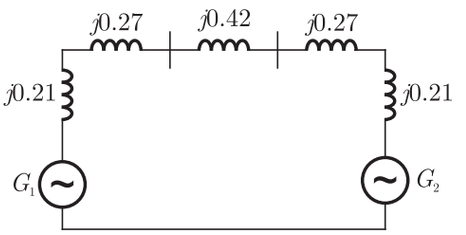
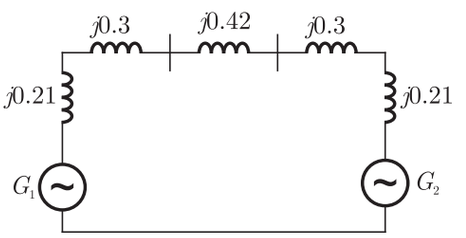
(B)



(C)



(D)



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MCQ 1.5.28 Out of the following plant categories

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(i) Nuclear

(ii) Run-of-river

(iii) Pump Storage

(iv) Diesel

The base load power plant are

(A) (i) and (ii)

(B) (ii) and (iii)

(C) (i), (ii) and (iv)

(D) (i), (iii) and (iv)

MCQ 1.5.29 For a fixed value of complex power flow in a transmission line having a sending end voltage V, the real loss will be proportional to

(A) V

(B) V^2

(C) $\frac{1}{V^2}$

(D) $\frac{1}{V}$

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MCQ 1.5.30 For the Y-bus matrix of a 4-bus system given in per unit, the buses having shunt elements are

$$Y_{BUS} = j\begin{bmatrix} -5 & 2 & 2.5 & 0 \\ 2 & -10 & 2.5 & 4 \\ 2.5 & 2.5 & -9 & 4 \\ 0 & 4 & 4 & -8 \end{bmatrix}$$

(A) 3 and 4

(B) 2 and 3

(C) 1 and 2

(D) 1, 2 and 4

MCQ 1.5.31 Match the items in List-I (To) with the items in the List-II (Use) and select the correct answer using the codes given below the lists.

	List-I		List-II
a.	improve power factor	1.	shunt reactor
b.	reduce the current ripples	2.	shunt capacitor
c.	increase the power flow in line	3.	series capacitor
d.	reduce the Ferranti effect	4.	series reactor

(A) a " 2, b " 3, c " 4, d " 1

(B) a " 2, b " 4, c " 3, d " 1

(C) a " 4, b " 3, c " 1, d " 2

(D) a " 4, b " 1, c " 3, d " 2

MCQ 1.5.32 Match the items in List-I (Type of transmission line) with the items in List-II (Type of distance relay preferred) and select the correct answer using the codes given below the lists.

	List-I		List-II
a.	Short Line	1.	Ohm Relay
b.	Medium Line	2.	Reactance Relay
c.	Long Line	3.	Mho Relay

(A) a " 2, b " 1, c " 3

(B) a " 3, b " 2, c " 1

(C) a " 1, b " 2, c " 3

(D) a " 1, b " 3, c " 2

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MCQ 1.5.33 Three generators are feeding a load of 100 MW. The details of the generators are

	Rating (MW)	Efficiency (%)	Regulation (Pu.) (on 100 MVA base)
Generator-1	100	20	0.02
Generator-2	100	30	0.04
Generator-3	100	40	0.03

In the event of increased load power demand, which of the following will happen ?
(A) All the generator will share equal power
(B) Generator-3 will share more power compared to Generator-1
(C) Generator-1 will share more power compared to Generator-2
(D) Generator-2 will share more power compared to Generator-3

MCQ 1.5.34 A 500 MW, 21 kV, 50 Hz, 3-phase, 2-pole synchronous generator having a rated p.f = 0.9, has a moment of inertia of $27.5 \# 10^3$ kg-m^2 .The inertia constant (H) will be
(A) 2.44 s (B) 2.71 s
(C) 4.88 s (D) 5.42 s

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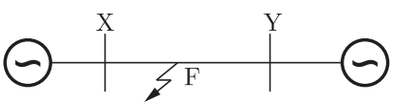
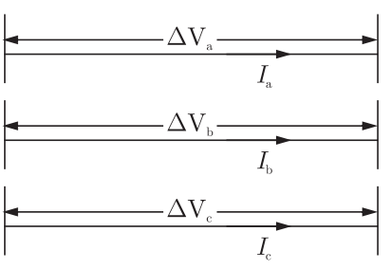
MCQ 1.5.35 A two machine power system is shown below. The Transmission line XY has positive sequence impedance of $Z_1\,\Omega$ and zero sequence impedance of $Z_0\,\Omega$



An 'a' phase to ground fault with zero fault impedance occurs at the centre of the transmission line. Bus voltage at X and line current from X to F for the phase 'a', are given by V_a Volts and I_a amperes, respectively. Then, the impedance measured by the ground distance relay located at the terminal X of line XY will be given by
(A) $\wedge Z_1/2\,\Omega$ (B) $\wedge Z_0/2\,\Omega$
(C) $(Z_0+Z_1)/2\,\Omega$ (D) $\wedge V_a/I_a\,\Omega$

MCQ 1.5.36 An extra high voltage transmission line of length 300 km can be approximate by a lossless line having propagation constant $\beta = 0.00127$ radians per km. Then the percentage ratio of line length to wavelength will be given by
(A) 24.24 % (B) 12.12 %
(C) 19.05 % (D) 6.06 %

MCQ 1.5.37 A-3-phase transmission line is shown in figure :



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Voltage drop across the transmission line is given by the following equation :

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

Shunt capacitance of the line can be neglect. If the has positive sequence impedance of $15\,\Omega$ and zero sequence impedance of $48\,\Omega$, then the values of Z_s and Z_m will be

(A) $Z_s = 31.5\,\Omega; Z_m = 16.5\,\Omega$

(B) $Z_s = 26\,\Omega; Z_m = 11\,\Omega$

(C) $Z_s = 16.5\,\Omega; Z_m = 31.5\,\Omega$

(D) $Z_s = 11\,\Omega; Z_m = 26\,\Omega$

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MCQ 1.5.38 Voltages phasors at the two terminals of a transmission line of length 70 km have a magnitude of 1.0 per unit but are 180 degree out of phase. Assuming that the maximum load current in the line is $1/5^{th}$ of minimum 3-phase fault current. Which one of the following transmission line protection schemes will not pick up for this condition ?

(A) Distance protection using ohm relay with zoen-1 set to 80% of the line impedance.

(B) Directional over current protection set to pick up at 1.25 times the maximum load current

(C) Pilot relaying system with directional comparison scheme

(D) Pilot relaying system with segregated phase comparison scheme

MCQ 1.5.39 A loss less transmission line having Surge Impedance Loading (SIL) of 2280 MW is provided with a uniformly distributed series capacitive compensation of 30%. Then, SIL of the compensated transmission line will be

(A) 1835 MW (B) 2280 MW

(C) 2725 MW (D) 3257 MW

MCQ 1.5.40 A loss less power system has to serve a load of 250 MW. There are tow generation (G_1 and G_2) in the system with cost curves C_1 and C_2 respectively defined as follows ;

$C_1(P_{G1}) = P_{G1} + 0.055 \# P_{G1}^2$

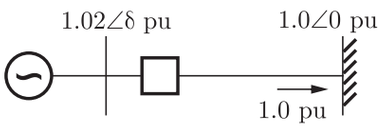
$C_2(P_{G2}) = 3P_{G2} + 0.03 \# P_{G2}^2$

Where P_{G1} and P_{G2} are the MW injections from generator G_1 and G_2respectively. Thus, the minimum cost dispatch will be

(A) $P_{G1} = 250$ MW; $P_{G2} = 0$ MW (B) $P_{G1} = 150$ MW; $P_{G2} = 100$ MW

(C) $P_{G1} = 100$ MW; $P_{G2} = 150$ MW (D) $P_{G1} = 0$ MW; $P_{G2} = 250$ MW

MCQ 1.5.41 A loss less single machine infinite bus power system is shown below :



The synchronous generator transfers 1.0 per unit of power to the infinite bus. The critical clearing time of circuit breaker is 0.28 s. If another identical synchronous

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generator is connected in parallel to the existing generator and each generator is scheduled to supply 0.5 per unit of power, then the critical clearing time of the circuit breaker will

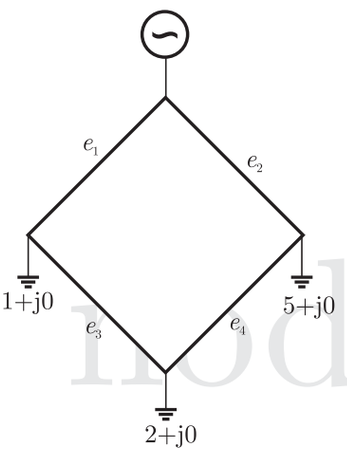
(A) reduce to 0.14 s

(B) reduce but will be more than 0.14 s

(C) remain constant at 0.28 s

(D) increase beyond 0.28 s

MCQ 1.5.42 Single line diagram of a 4-bus single source distribution system is shown below. Branches e_1, e_2, e_3 and e_4 have equal impedances. The load current values indicated in the figure are in per unit.



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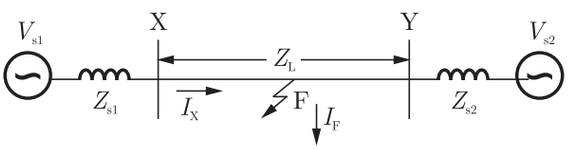
Distribution company's policy requires radial system operation with minimum loss. This can be achieved by opening of the branch

(A) e_1 (B) e_2

(C) e_3 (D) e_4

Data for Q.43 and Q.44 are given below. Solve the problems and choose the correct answers.



Given that: $V_{s1} = V_{s2} = 1 + j0$ p.u;

The positive sequence impedance are

$Z_{s1} = Z_{s2} = 0.001 + j0.01$ p.u and $Z_L = 0.006 + j0.06$ p.u

3-phase Base MVA = 100

voltage base = 400 kV(Line to Line)

Nominal system frequency= 50 Hz.

The reference voltage for phase 'a' is defined as $V(t) = V_m \cos(\omega t)$.

A symmetrical three phase fault occurs at centre of the line, i.e. point 'F' at time 't_0'. The positive sequence impedance from source S_1 to point 'F' equals $0.004 + j0.04$ p.u. The wave form corresponding to phase 'a' fault current from bus X reveals that decaying d.c. offset current is negative and in magnitude at its maximum initial value, Assume that the negative sequence impedances are equal

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to positive sequence impedance and the zero sequence impedances are three times positive sequence impedances.

MCQ 1.5.43 The instant (t_0) of the fault will be

(A) 4.682 ms (B) 9.667 ms

(C) 14.667 ms (D) 19.667 ms

MCQ 1.5.44 The rms value of the component of fault current (I_f) will be

(A) 3.59 kA (B) 5.07 kA

(C) 7.18 kA (D) 10.15 kA

MCQ 1.5.45 Instead of the three phase fault, if a single line to ground fault occurs on phase 'a' at point 'F' with zero fault impedance, then the rms of the ac component of fault current (I_x) for phase 'a' will be

(A) 4.97 p.u (B) 7.0 p.u

(C) 14.93 p.u (D) 29.85 p.u

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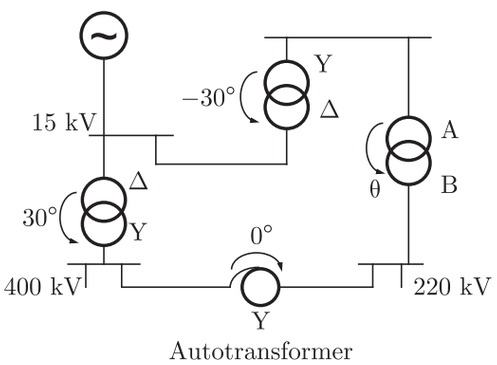
MCQ 1.5.46 Consider the transformer connections in a part of a power system shown in the figure. The nature of transformer connections and phase shifts are indicated for all but one transformer

Which of the following connections, and the corresponding phase shift θ, should be used for the transformer between A and B ?



Autotransformer

(A) Star-star ($\theta = 0^{\circ}$) (B) Star-Delta ($\theta = -30^{\circ}$)

(C) Delta-star ($\theta = 30^{\circ}$) (D) Star-Zigzag ($\theta = 30^{\circ}$)

MCQ 1.5.47 The incremental cost curves in Rs/MWhr for two generators supplying a common load of 700 MW are shown in the figures. The maximum and minimum generation limits are also indicated. The optimum generation schedule is :

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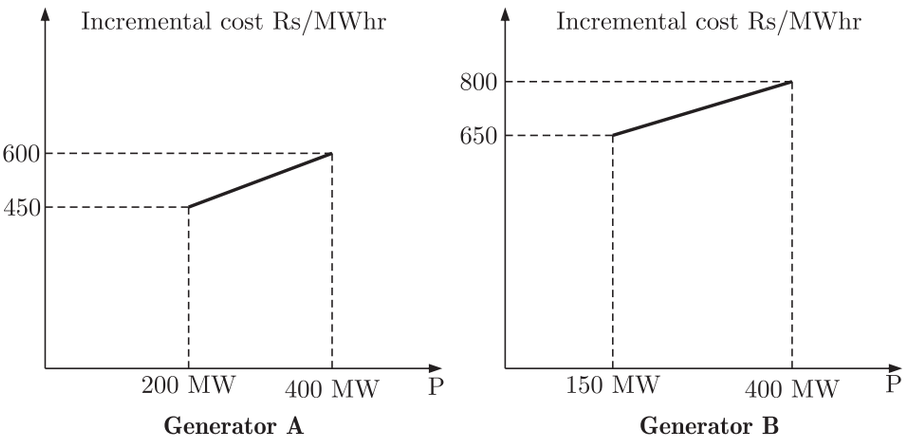

(A) Generator A : 400 MW, Generator B : 300 MW

(B) Generator A : 350 MW, Generator B : 350 MW

(C) Generator A : 450 MW, Generator B : 250 MW

(D) Generator A : 425 MW, Generator B : 275 MW

MCQ 1.5.48 Two regional systems, each having several synchronous generators and loads are inter connected by an ac line and a HVDC link as shown in the figure. Which of the following statements is true in the steady state :

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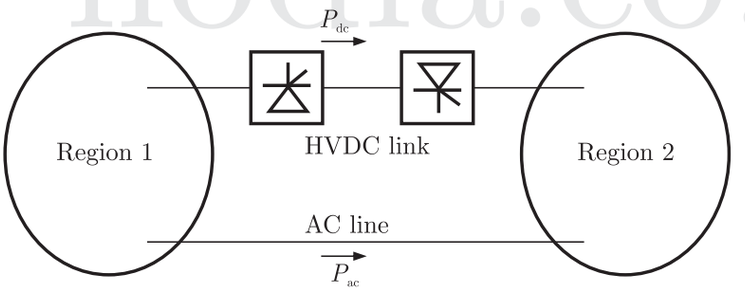


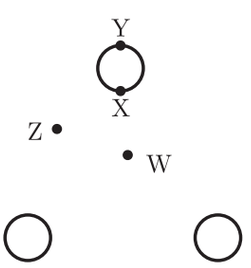
(A) Both regions need not have the same frequency

(B) The total power flow between the regions $(P_{ac} + P_{dc})$ can be changed by controlled the HDVC converters alone

(C) The power sharing between the ac line and the HVDC link can be changed by controlling the HDVC converters alone.

(D) The directions of power flow in the HVDC link (P_{dc}) cannot be reversed

MCQ 1.5.49 Considered a bundled conductor of an overhead line consisting of three identical sub-conductors placed at the corners of an equilateral triangle as shown in the figure. If we neglect the charges on the other phase conductor and ground, and assume that spacing between sub-conductors is much larger than their radius, the maximum electric field intensity is experienced at



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(A) Point X (B) Point Y
(C) Point Z (D) Point W

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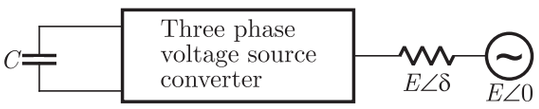
MCQ 1.5.50 The figure below shows a three phase self-commutated voltage source converter connected to a power system. The converter's dc bus capacitor is marked as C in the figure. The circuit in initially operating in steady state with $\delta = 0$ and the capacitor dc voltage is equal to V_{dc0}. You may neglect all losses and harmonics. What action should be taken to increase the capacitor dc voltage slowly to a new steady state value.



(A) Make δ positive and maintain it at a positive value
(B) Make δ positive and return it to its original value
(C) Make δ negative and maintain it at a negative value
(D) Make δ negative and return it to its original value

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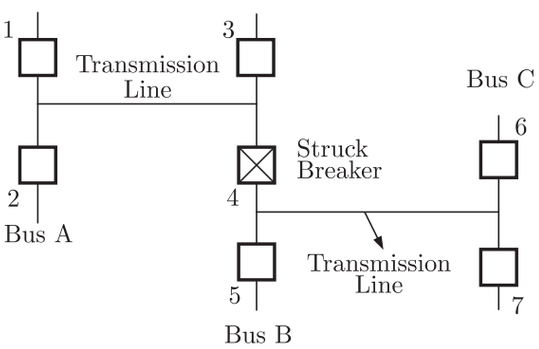
MCQ 1.5.51 The total reactance and total suspectance of a lossless overhead EHV line, operating at 50 Hz, are given by 0.045 pu and 1.2 pu respectively. If the velocity of wave propagation is $3 \# 10^5$ km/s, then the approximate length of the line is
(A) 122 km (B) 172 km
(C) 222 km (D) 272 km

MCQ 1.5.52 Consider the protection system shown in the figure below. The circuit breakers numbered from 1 to 7 are of identical type. A single line to ground fault with zero fault impedance occurs at the midpoint of the line (at point F), but circuit breaker 4 fails to operate ("Stuck breaker"). If the relays are coordinated correctly, a valid sequence of circuit breaker operation is



(A) 1, 2, 6, 7, 3, 5 (B) 1, 2, 5, 5, 7, 3
(C) 5, 6, 7, 3, 1, 2 (D) 5, 1, 2, 3, 6, 7

MCQ 1.5.53 A three phase balanced star connected voltage source with frequency ω rad/s is connected to a star connected balanced load which is purely inductive. The instantaneous line currents and phase to neutral voltages are denoted by (i_a, i_b, i_c) and (V_{an}, V_{bn}, V_{cn}) respectively, and their rms values are denoted by V and I.

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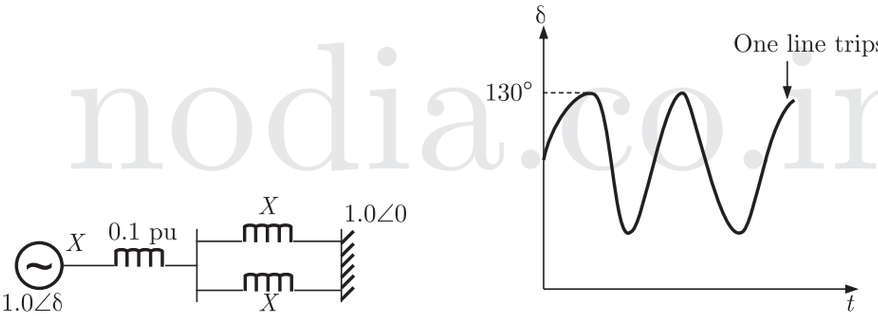
If $R = \begin{bmatrix} 0 & \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} \\ -\frac{1}{\sqrt{3}} & 0 & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} & 0 \end{bmatrix}$, then the magnitude of

of R is

(A) $3VI$ (B) VI

(C) $0.7VI$ (D) 0

MCQ 1.5.54 Consider a synchronous generator connected to an infinite bus by two identical parallel transmission line. The transient reactance 'x' of the generator is 0.1 pu and the mechanical power input to it is constant at 1.0 pu. Due to some previous disturbance, the rotor angle (δ) is undergoing an undamped oscillation, with the maximum value of $\delta(t)$ equal to 130° .One of the parallel lines trip due to the relay maloperation at an instant when $\delta(t) = 130^\circ$ as shown in the figure. The maximum value of the per unit line reactance, x such that the system does not lose synchronism subsequent to this tripping is



(A) 0.87 (B) 0.74

(C) 0.67 (D) 0.54

MCQ 1.5.55 Suppose we define a sequence transformation between "a-b-c" and "p-n-o" variables as follows :

$$\begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix} = k \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix} \begin{bmatrix} f_p \\ f_n \\ f_o \end{bmatrix}$$ where $\alpha = e^{j\frac{2\pi}{3}}$ and k and is a constant

Now, if it is given that : $\begin{bmatrix} V_p \\ V_n \\ V_o \end{bmatrix} = \begin{bmatrix} 0.5 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 2.0 \end{bmatrix} \begin{bmatrix} i_p \\ i_n \\ i_0 \end{bmatrix}$ and $\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = Z \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$ then,

(A) $Z = \begin{bmatrix} 1.0 & 0.5 & 0.75 \\ 0.75 & 1.0 & 0.5 \\ 0.5 & 0.75 & 1.0 \end{bmatrix}$ (B) $Z = \begin{bmatrix} 1.0 & 0.5 & 0.5 \\ 0.5 & 1.0 & 0.5 \\ 0.5 & 0.5 & 1.0 \end{bmatrix}$

(C) $Z = 3k^2 \begin{bmatrix} 1.0 & 0.75 & 0.5 \\ 0.5 & 1.0 & 0.75 \\ 0.75 & 0.5 & 1.0 \end{bmatrix}$ (D) $Z = \frac{k^2}{3} \begin{bmatrix} 1.0 & -0.5 & -0.5 \\ -0.5 & 1.0 & -0.5 \\ -0.5 & -0.5 & 1.0 \end{bmatrix}$

MCQ 1.5.56 Consider the two power systems shown in figure A below, which are initially not interconnected, and are operating in steady state at the same frequency. Separate load flow solutions are computed individually of the two systems, corresponding to this scenario. The bus voltage phasors so obtain are indicated on figure A. These two isolated systems are now interconnected by a short transmission line as shown in figure B, and it is found that $P_1 = P_2 = Q_1 = Q_2 = 0$.

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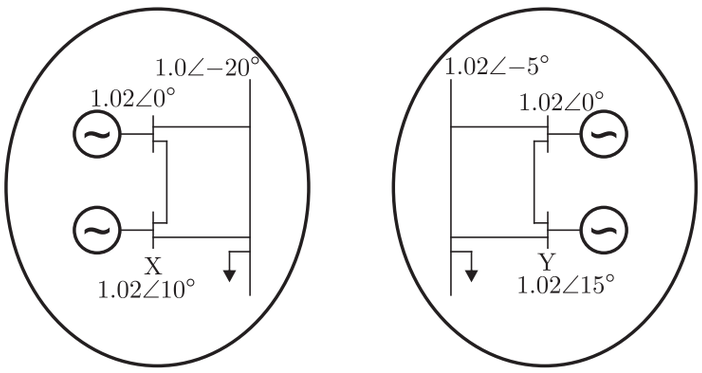

Fig A

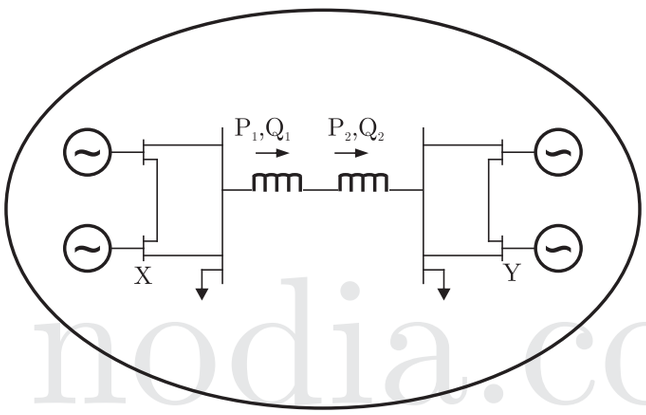

Fig B

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The bus voltage phase angular difference between generator bus X and generator bus Y after interconnection is

(A) 10c (B) 25°

(C) −30c (D) 30°

MCQ 1.5.57 A 230 V (Phase), 50 Hz, three-phase, 4-wire, system has a phase sequence ABC. A unity power-factor load of 4 kW is connected between phase A and neutral N. It is desired to achieve zero neutral current through the use of a pure inductor and a pure capacitor in the other two phases. The value of inductor and capacitor is

(A) 72.95 mH in phase C and 139.02 μF in Phase B

(B) 72.95 mH in Phase B and 139.02 μF in Phase C

(C) 42.12 mH in Phase C and 240.79 μF in Phase B

(D) 42.12 mH in Phase B and 240.79 μF in Phase C

MCQ 1.5.58 An isolated 50 Hz synchronous generator is rated at 15 MW which is also the maximum continuous power limit of its prime mover. It is equipped with a speed governor with 5% droop. Initially, the generator is feeding three loads of 4 MW each at 50 Hz. One of these loads is programmed to trip permanently if the frequency falls below 48 Hz .If an additional load of 3.5 MW is connected then the frequency will settle down to

(A) 49.417 Hz (B) 49.917 Hz

(C) 50.083 Hz (D) 50.583 Hz

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MCQ 1.5.59 The concept of an electrically short, medium and long line is primarily based on the

(A) nominal voltage of the line

(B) physical length of the line

(C) wavelength of the line

(D) power transmitted over the line

MCQ 1.5.60 Keeping in view the cost and overall effectiveness, the following circuit breaker is best suited for capacitor bank switching

(A) vacuum (B) air blast

(C) SF_6 (D) oil

MCQ 1.5.61 In a biased differential relay the bias is defined as a ratio of

(A) number of turns of restraining and operating coil

(B) operating coil current and restraining coil current

(C) fault current and operating coil current

(D) fault current and restraining coil current

MCQ 1.5.62 An HVDC link consist of rectifier, inverter transmission line and other equipments. Which one of the following is true for this link ?

(A) The transmission line produces/ supplies reactive power

(B) The rectifier consumes reactive power and the inverter supplies reactive power from/ to the respective connected AC systems

(C) Rectifier supplies reactive power and the inverted consumers reactive power to/ from the respective connected AC systems

(D) Both the converters (rectifier and inverter) consume reactive power from the respective connected AC systems

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MCQ 1.5.63 The A, B, C, D constants of a 220 kV line are :

$A = D = 0.94\angle 1^\circ$, $B = 130\angle 73^\circ$, $C = 0.001\angle 90^\circ$

If the sending end voltage of the line for a given load delivered at nominal voltage is 240 kV, the % voltage regulation of the line is

(A) 5 (B) 9

(C) 16 (D) 21

MCQ 1.5.64 A single phase transmission line and a telephone line are both symmetrically strung one below the other, in horizontal configurations, on a common tower, The shortest and longest distances between the phase and telephone conductors are 2.5 m and 3 m respectively.

The voltage (volt/km) induced in the telephone circuit, due to 50 Hz current of 100 amps in the power circuit is

(A) 4.81 (B) 3.56

(C) 2.29 (D) 1.27

MCQ 1.5.65 Three identical star connected resistors of 1.0 pu are connected to an unbalanced 3-phase supply. The load neutral is isolated. The symmetrical components of the

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line voltages in pu. are: $V_{ab_1} = X + \theta_1$, $V_{ab_2} = Y + \theta_2$. If all the pu calculations are with the respective base values, the phase to neutral sequence voltages are

(A) $V_{an_1} = X + (\theta_1 + 30°), V_{an_2} = Y(\theta_2 - 30°)$

(B) $V_{an_1} = X + (\theta_1 - 30°), V_{an_2} = Y + (\theta_2 + 30°)$

(C) $V_{an_1} = \frac{1}{\sqrt{3}} X + (\theta_1 - 30°), V_{an_2} = \frac{1}{\sqrt{3}} Y + (\theta_2 - 30°)$

(D) $V_{an_1} = \frac{1}{\sqrt{3}} X + (\theta_1 - 60°), V_{an_2} = \frac{1}{\sqrt{3}} Y + (\theta_2 - 60°)$

MCQ 1.5.66 A generator is connected through a 20 MVA, 13.8/138 kV step down transformer, to a transmission line. At the receiving end of the line a load is supplied through a step down transformer of 10 MVA, 138/69 kV rating. A 0.72 pu. load, evaluated on load side transformer ratings as base values , is supplied from the above system. For system base values of 10 MVA and 69 kV in load circuit, the value of the load (in per unit) in generator will be

(A) 36 (B) 1.44

(C) 0.72 (D) 0.18

MCQ 1.5.67 The Gauss Seidel load flow method has following disadvantages.
Tick the incorrect statement.

(A) Unreliable convergence

(B) Slow convergence

(C) Choice of slack bus affects convergence

(D) A good initial guess for voltages is essential for convergence

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Data for Q. 68 and Q. 69 are given below. Solve the problems and choose the correct answers.

A generator feeds power to an infinite bus through a double circuit transmission line. A 3-phase fault occurs at the middle point of one of the lines. The infinite bus voltage is 1 pu, the transient internal voltage of the generator is 1.1 pu and the equivalent transfer admittance during fault is 0.8 pu. The 100 MVA generator has an inertia constant of 5 MJ/MVA and it was delivering 1.0 pu power prior of the fault with rotor power angle of 30°. The system frequency is 50 Hz.

MCQ 1.5.68 The initial accelerating power (in pu) will be

(A) 1.0 (B) 0.6

(C) 0.56 (D) 0.4

MCQ 1.5.69 If the initial accelerating power is X pu, the initial acceleration in elect-deg/sec, and the inertia constant in MJ-sec/elect-deg respectively will be

(A) $31.4X$, 18 (B) $1800X$, 0.056

(C) $X/1800$, 0.056 (D) $X/31.4$, 18

Data for Q.70 and Q.71 are given below. Solve the problems and choose the correct answers.

For a power system the admittance and impedance matrices for the fault studies are as follows.

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$$Y_{\text{bus}} = \begin{bmatrix} -j8.75 & j1.25 & j2.50 \\ j1.25 & -j6.25 & j2.50 \\ j2.50 & -j2.50 & -j5.00 \end{bmatrix} \quad Z_{\text{bus}} = \begin{bmatrix} j0.16 & j0.08 & j0.12 \\ j0.08 & j0.24 & j0.16 \\ j0.12 & j0.16 & j0.34 \end{bmatrix}$$

The pre-fault voltages are 1.0 pu. at all the buses. The system was unloaded prior to the fault. A solid 3-phase fault takes place at bus 2.

MCQ 1.5.70 The post fault voltages at buses 1 and 3 in per unit respectively are

(A) 0.24, 0.63 (B) 0.31, 0.76

(C) 0.33, 0.67 (D) 0.67, 0.33

MCQ 1.5.71 The per unit fault feeds from generators connected to buses 1 and 2 respectively are

(A) 1.20, 2.51 (B) 1.55, 2.61

(C) 1.66, 2.50 (D) 5.00, 2.50

MCQ 1.5.72 A 400 V, 50 Hz, three phase balanced source supplies power to a star connected load whose rating is $12\sqrt{3}$ kVA, 0.8 pf (lag). The rating (in kVAR) of the delta connected (capacitive) reactive power bank necessary to bring the pf to unity is

(A) 28. 78 (B) 21.60

(C) 16.60 (D) 12.47

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MCQ 1.5.73 The p.u. parameter for a 500 MVA machine on its own base are:
inertia, $M = 20$ p.u. ; reactance, $X = 2$ p.u.
The p.u. values of inertia and reactance on 100 MVA common base, respectively, are

(A) 4, 0.4 (B) 100, 10

(C) 4, 10 (D) 100, 0.4

MCQ 1.5.74 An 800 kV transmission line has a maximum power transfer capacity of P. If it is operated at 400 kV with the series reactance unchanged, the new maximum power transfer capacity is approximately

(A) P (B) $2P$

(C) $P/2$ (D) $P/4$

MCQ 1.5.75 The insulation strength of an EHV transmission line is mainly governed by

(A) load power factor (B) switching over-voltages

(C) harmonics (D) corona

MCQ 1.5.76 High Voltage DC (HVDC) transmission is mainly used for

(A) bulk power transmission over very long distances

(C) inter-connecting two systems with same nominal frequency

(C) eliminating reactive power requirement in the operation

(D) minimizing harmonics at the converter stations

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MCQ 1.5.77 The parameters of a transposed overhead transmission line are given as :
Self reactance $X_S = 0.4\Omega$/km and Mutual reactance $X_m = 0.1\Omega$/km The positive sequence reactance X_1 and zero sequence reactance X_0, respectively in Ω/km are

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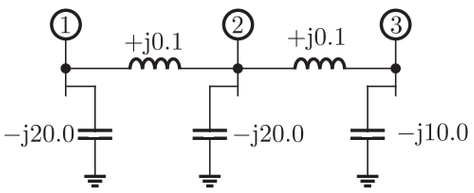
(A) 0.3, 0.2 (B) 0.5, 0.2
(C) 0.5, 0.6 (D) 0.3, 0.6

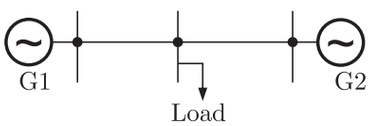
MCQ 1.5.78 At an industrial sub-station with a 4 MW load, a capacitor of 2 MVAR is installed to maintain the load power factor at 0.97 lagging. If the capacitor goes out of service, the load power factor becomes
(A) 0.85 (B) 1.00
(C) 0.80 lag (D) 0.90 lag

MCQ 1.5.79 The network shown in the given figure has impedances in p.u. as indicated. The diagonal element Y_{22} of the bus admittance matrix Y_{BUS} of the network is



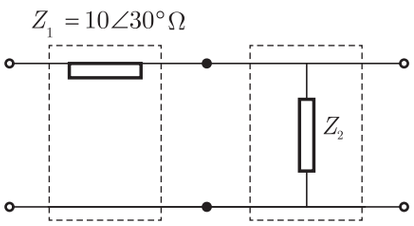
(A) $-j19.8$ (B) $+j20.0$
(C) $+j0.2$ (D) $-j19.95$

MCQ 1.5.80 A load centre is at an equidistant from the two thermal generating stations G_1 and G_2 as shown in the figure. The fuel cost characteristic of the generating stations are given by
$F_1 = a + bP_1 + cP_1^2$ Rs/hour
$F_2 = a + bP_2 + 2cP_2^2$ Rs/ hour



Where P_1 and P_2 are the generation in MW of G_1 and G_2, respectively. For most economic generation to meet 300 MW of load P_1 and P_2 respectively, are
(A) 150, 150 (B) 100, 200
(C) 200, 100 (D) 175, 125

MCQ 1.5.81 Two networks are connected in cascade as shown in the figure. With usual notations the equivalent A, B, C and D constants are obtained. Given that, $C = 0.025 + 45°$, the value of Z_2 is



(A) $10 + 30°\,\Omega$ (B) $40 + -45°\,\Omega$
(C) $1\,\Omega$ (D) $0\,\Omega$

MCQ 1.5.82 A generator with constant 1.0 p.u. terminal voltage supplies power through a step-up transformer of 0.12 p.u. reactance and a

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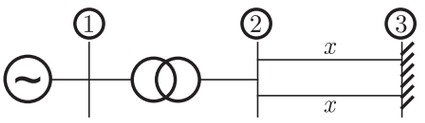
double-circuit line to an infinite bus bar as shown in the figure. The infinite bus voltage is maintained at 1.0 p.u. Neglecting the resistances and suspectances of the system, the steady state stability power limit of the system is 6.25 p.u. If one of the double-circuit is tripped, then resulting steady state stability power limit in p.u. will be



(A) 12.5 p.u.
(B) 3.125 p.u.
(C) 10.0 p.u.
(D) 5.0 p.u.

Data for Q.83 and Q.84 are given below. Solve the problems and choose the correct answers

At a 220 kV substation of a power system, it is given that the three-phase fault level is 4000 MVA and single-line to ground fault level is 5000 MVA Neglecting the resistance and the shunt suspectances of the system.

MCQ 1.5.83 The positive sequence driving point reactance at the bus is
(A) 2.5 Ω
(B) 4.033 Ω
(C) 5.5 Ω
(D) 12.1 Ω

MCQ 1.5.84 The zero sequence driving point reactance at the bus is
(A) 2.2 Ω
(B) 4.84 Ω
(C) 18.18 Ω
(D) 22.72 Ω

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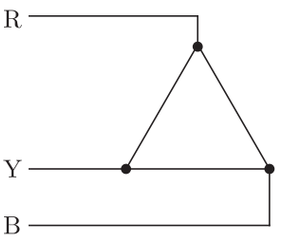
MCQ 1.5.85 Total instantaneous power supplied by a 3-phase ac supply to a balanced R-L load is
(A) zero
(B) constant
(C) pulsating with zero average
(D) pulsating with the non-zero average

MCQ 1.5.86 The rated voltage of a 3-phase power system is given as
(A) rms phase voltage
(B) peak phase voltage
(C) rms line to line voltage
(D) peak line to line voltage

MCQ 1.5.87 The phase sequences of the 3-phase system shown in figure is



(A) RYB
(B) RBY

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(C) BRY (D) YBR

MCQ 1.5.88 In the thermal power plants, the pressure in the working fluid cycle is developed by

(A) condenser (B) super heater

(C) feed water pump (D) turbine

MCQ 1.5.89 For harnessing low variable waterheads, the suitable hydraulic turbine with high percentage of reaction and runner adjustable vanes is

(A) Kaplan (B) Francis

(C) Pelton (D) Impeller

MCQ 1.5.90 The transmission line distance protection relay having the property of being inherently directional is

(A) impedance relay (B) MHO relay

(C) OHM relay (D) reactance relay

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MCQ 1.5.91 A 800 kV transmission line is having per phase line inductance of 1.1 mH/km and per phase line capacitance of 11.68 nF/km. Ignoring the length of the line, its ideal power transfer capability in MW is

(A) 1204 MW (B) 1504 MW

(C) 2085 MW (D) 2606 MW

MCQ 1.5.92 A 110 kV, single core coaxial, XLPE insulated power cable delivering power at 50 Hz, has a capacitance of 125 nF/km. If the dielectric loss tangent of XLPE is $2 \# 10^{-4}$, then dielectric power loss in this cable in W/km is

(A) 5.0 (B) 31.7

(C) 37.8 (D) 189.0

MCQ 1.5.93 A lightning stroke discharges impulse current of 10 kA (peak) on a 400 kV transmission line having surge impedance of 250 Ω The magnitude of transient over-voltage travelling waves in either direction assuming equal distribution from the point of lightning strike will be

(A) 1250 kV (B) 1650 kV

(C) 2500 kV (D) 2900 kV

MCQ 1.5.94 The generalized circuit constants of a 3-phase, 220 kV rated voltage, medium length transmission line are

$$A = D = 0.936 + j0.016 = 0.936 + 0.98\angle$$
$$B = 35.5 + j138 = 142.0 + 76.4\angle\,\Omega$$
$$C = (-5.18 + j914) \# 10^{-6}\,\Omega$$

If the load at the receiving end is 50 MW at 220 kV with a power factor of 0.9 lagging, then magnitude of line to line sending end voltage should be

(A) 133.23 kV (B) 220.00 kV

(C) 230. 78 kV (D) 246.30 kV

MCQ 1.5.95 A new generator having $E_g = 1.4 + 30\angle$ pu. [equivalent to $(1.212 + j0.70)$ pu] and synchronous reactance 'X_S' of 1.0 pu on the system base, is to be connected to a bus having voltage V_t, in the existing power system. This

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existing power system can be represented by Thevenin's voltage $E_{th} = 0.9\angle 0°$ pu in series with Thevenin's impedance $Z_{th} = 0.25\angle 90°$ pu. The magnitude of the bus voltage V_t of the system in pu will be

(A) 0.990 (B) 0.973

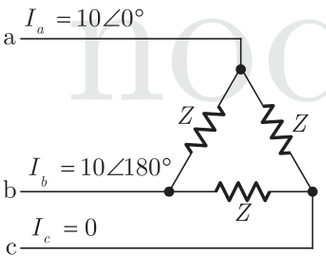
(C) 0.963 (D) 0.900

MCQ 1.5.96 A 3-phase generator rated at 110 MVA, 11 kV is connected through circuit breakers to a transformer . The generator is having direct axis sub-transient reactance $X''_d = 19\%$, transient reactance $X'_d = 26\%$ and synchronous reactance $=130\%$. The generator is operating at no load and rated voltage when a three phase short circuit fault occurs between the breakers and the transformer . The magnitude of initial symmetrical rms current in the breakers will be

(A) 4.44 kA (B) 22.20 kA

(C) 30.39 kA (D) 38.45 kA

MCQ 1.5.97 A 3-phase transmission line supplies **3**-connected load Z. The conductor 'c' of the line develops an open circuit fault as shown in figure. The currents in the lines are as shown on the diagram. The +ve sequence current component in line 'a' will be



(A) $5.78\angle -30°$ (B) $5.78\angle 90°$

(C) $6.33\angle 90°$ (D) $10.00\angle -30°$

MCQ 1.5.98 A 500 MVA, 50 Hz, 3-phase turbo-generator produces power at 22 kV. Generator is Y-connected and its neutral is solidly grounded. It sequence reactances are $X_1 = X_2 = 0.15$ pu and $X_0 = 0.05$ pu.It is operating at rated voltage and disconnected from the rest of the system (no load). The magnitude of the sub-transient line current for single line to ground fault at the generator terminal in pu will be

(A) 2.851 (B) 3.333

(C) 6.667 (D) 8.553

MCQ 1.5.99 A 50 Hz, 4-pole, 500 MVA, 22 kV turbo-generator is delivering rated megavolt-amperes at 0.8 power factor. Suddenly a fault occurs reducing in electric power output by 40%. Neglect losses and assume constant power input to the shaft. The accelerating torque in the generator in MNm at the time of fault will be

(A) 1.528 (B) 1.018

(C) 0.848 (D) 0.509

MCQ 1.5.100 A hydraulic turbine having rated speed of 250 rpm is connected to a synchronous generator. In order to produce power at 50 Hz, the number of poles required in the generator are

(A) 6 (B) 12

(C) 16 (D) 24

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MCQ 1.5.101 Bundled conductors are mainly used in high voltage overhead transmission lines to

(A) reduces transmission line losses

(B) increase mechanical strength of the line

(C) reduce corona

(D) reduce sag

MCQ 1.5.102 A power system consist of 300 buses out of which 20 buses are generator bus, 25 buses are the ones with reactive power support and 15 buses are the ones with fixed shunt capacitors. All the other buses are load buses. It is proposed to perform a load flow analysis in the system using Newton-Raphson method. The size of the Newton Raphson Jacobian matrix is

(A) 553×553 (B) 540×540

(C) 555×555 (D) 554×554

MCQ 1.5.103 Choose two appropriate auxiliary components of a HVDC transmission system from the following

P. D.C line inductor

Q. A.C line inductor

R. Reactive power sources

S. Distance relays on D.C line

T. Series capacitance on A.C. line

(A) P and Q (B) P and R

(C) Q and S (D) S and T

MCQ 1.5.104 A round rotor generator with internal voltage $E_1 = 2.0$ pu and $X = 1.1$ pu is connected to a round rotor synchronous motor with internal voltage $E_2 = 1.3$ pu and $X = 1.2$ pu. The reactance of the line connecting the generator to the motor is 0.5 pu. When the generator supplies 0.5 pu power, the rotor angle difference between the machines will be

(A) 57.42° (B) 1°

(C) 32.58° (D) 122.58°

MCQ 1.5.105 The interrupting time of a circuit breaker is the period between the instant of

(A) initiation of short circuit and the arc extinction on an opening operation

(B) energizing of the trip circuit and the arc extinction on an opening operation

(C) initiation of short circuit and the parting of primary arc contacts

(D) energizing of the trip circuit and the parting of primary arc contacts

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MCQ 1.5.106 The $ABCD$ parameters of a 3-phase overhead transmission line are $A = D = 0.9 \angle 0^{\circ}, B = 200 \angle 90^{\circ}\,\Omega$ and $C = 0.95 \times 10^{-3} \angle 90^{\circ}$ S. At no-load condition a shunt inductive, reactor is connected at the receiving end of the line to limit the receiving-end voltage to be equal to the sending-end voltage. The ohmic value of the reactor is

(A) $3\,\Omega$ (B) $2000\,\Omega$

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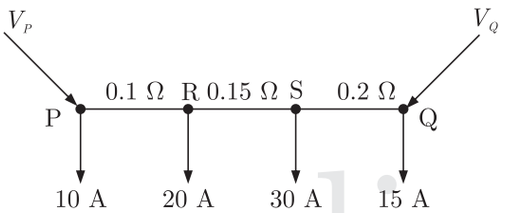
(C) 105.26 Ω (D) 1052.6 Ω

MCQ 1.5.107 A surge of 20 kV magnitude travels along a lossless cable towards its junction with two identical lossless overhead transmission lines. The inductance and the capacitance of the cable are 0.4 mH and 0.5 μF per km. The inductance and capacitance of the overhead transmission lines are 1.5 mH and 0.015 μF per km. The magnitude of the voltage at the junction due to surge is

(A) 36.72 kV (B) 18.36 kV

(C) 6.07 kV (D) 33.93 kV

MCQ 1.5.108 A dc distribution system is shown in figure with load current as marked. The two ends of the feeder are fed by voltage sources such that $V_P - V_Q = 3$ V. The value of the voltage V_P for a minimum voltage of 220 V at any point along the feeder is



(A) 225.89 V (B) 222.89 V

(C) 220.0 V (D) 228.58 V

MCQ 1.5.109 A 3-phase 11 kV generator feeds power to a constant power unity power factor load of 100 MW through a 3-phase transmission line. The line-to line voltage at the terminals of the machine is maintained constant at 11 kV. The per unit positive sequence impedance of the line based on 100 MVA and 11 kV is $j0.2$. The line to line voltage at the load terminals is measured to be less than 11 kV. The total reactive power to be injected at the terminals of the load to increase the line-to-line voltage at the load terminals to 11 kV is

(A) 100 MVAR (B) 10.1 MVAR

(C) −100 MVAR (D) −10.1 MVAR

MCQ 1.5.110 The bus impedance matrix of a 4-bus power system is given by

$$Z_{\text{bus}} = \begin{bmatrix} j0.3435 & j0.2860 & j0.2723 & j0.2277 \\ j0.2860 & j0.3408 & j0.2586 & j0.2414 \\ j0.2723 & j0.2586 & j0.2791 & j0.2209 \\ j0.2277 & j0.2414 & j0.2209 & j0.2791 \end{bmatrix}$$

A branch having an impedance of $j0.2\,\Omega$ is connected between bus 2 and the reference. Then the values of $Z_{22,\text{new}}$ and $Z_{23,\text{new}}$ of the bus impedance matrix of the modified network are respectively

(A) $j0.5408$ Ω and $j0.4586$ Ω

(B) $j0.1260$ Ω and $j0.0956$ Ω

(C) $j0.5408$ Ω and $j0.0956$ Ω

(D) $j0.1260$ Ω and $j0.1630$ Ω

MCQ 1.5.111 A 20-MVA, 6.6-kV, 3-phase alternator is connected to a 3-phase transmission line. The per unit positive-sequence, negative-sequence and zero-sequence impedances of the alternator are $j0.1$, $j0.1$ and $j0.04$ respectively. The neutral of the alternator

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is connected to ground through an inductive reactor of $j0.05$ p.u. The per unit positive-, negative- and zero-sequence impedances of transmission line are $j0.1$, $j0.1$ and $j0.3$, respectively. All per unit values are based on the machine ratings. A solid ground fault occurs at one phase of the far end of the transmission line. The voltage of the alternator neutral with respect to ground during the fault is

(A) 513.8 V (B) 889.9 V

(C) 1112.0 V (D) 642.2 V

MCQ 1.5.112 Incremental fuel costs (in some appropriate unit) for a power plant consisting of three generating units are

$IC_1 = 20 + 0.3P_1$, $IC_2 = 30 + 0.4P_2$, $IC_3 = 30$

Where P_1 is the power in MW generated by unit i for $i = 1, 2$ and 3. Assume that all the three units are operating all the time. Minimum and maximum loads on each unit are 50 MW and 300 MW respectively. If the plant is operating on economic load dispatch to supply the total power demand of 700 MW, the power generated by each unit is

(A) $P_1 = 242.86$ MW; $P_2 = 157.14$ MW; and $P_3 = 300$ MW

(B) $P_1 = 157.14$ MW; $P_2 = 242.86$ MW; and $P_3 = 300$ MW

(C) $P_1 = 300$ MW; $P_2 = 300$ MW; and $P_3 = 100$ MW

(D) $P_1 = 233.3$ MW; $P_2 = 233.3$ MW; and $P_3 = 233.4$ MW

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MCQ 1.5.113 A list of relays and the power system components protected by the relays are given in List-I and List-II respectively. Choose the correct match from the four choices given below:

	List-I		List-II
P.	Distance relay	1.	Transformers
Q.	Under frequency relay	2.	Turbines
R.	Differential relay	3.	Busbars
S.	Buchholz relay	4.	Shunt capacitors
		5.	Alternators
		6.	Transmission lines

Codes:

	P	Q	R	S
(A)	6	5	3	1
(B)	4	3	2	1
(C)	5	2	1	6
(D)	6	4	5	3

MCQ 1.5.114 A generator delivers power of 1.0 p.u. to an infinite bus through a purely reactive network. The maximum power that could be delivered by the generator is 2.0 p.u. A three-phase fault occurs at the terminals of the generator which reduces the generator output to zero. The fault is cleared after t_c second. The original network is then restored. The maximum swing of the rotor angle is found to be $\delta_{max} = 110$ electrical degree. Then the rotor angle in electrical degrees at $t = t_c$ is

(A) 55 (B) 70

(C) 69.14 (D) 72.4

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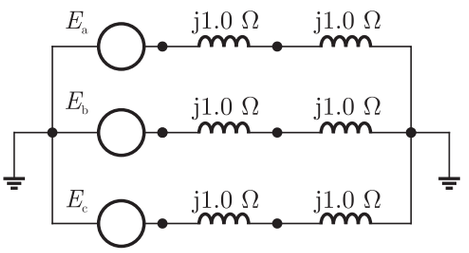
MCQ 1.5.115 A three-phase alternator generating unbalanced voltages is connected to an unbalanced load through a 3-phase transmission line as shown in figure. The neutral of the alternator and the star point of the load are solidly grounded. The phase voltages of the alternator are $E_a = 10\angle 0^\circ\,\text{V}$, $E_b = 10\angle -90^\circ\,\text{V}$, $E_c = 10\angle 120^\circ\,\text{V}$. The positive-sequence component of the load current is



(A) $1.31\angle -107^\circ$ A (B) $0.332\angle -120^\circ$ A

(C) $0.996\angle -120^\circ$ A (D) $3.51\angle -81^\circ$ A

MCQ 1.5.116 A balanced delta connected load of $(8 + j6)\,\Omega$ per phase is connected to a 400 V, 50 Hz, 3-phase supply lines. If the input power factor is to be improved to 0.9 by connecting a bank of star connected capacitor the required kVAR of the of the bank is

(A) 42.7 (B) 10.2

(C) 28.8 (D) 38.4

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MCQ 1.5.117 Consider a power system with three identical generators. The transmission losses are negligible. One generator(G1) has a speed governor which maintains its speed constant at the rated value, while the other generators(G2 and G3) have governors with a droop of 5%. If the load of the system is increased, then in steady state.

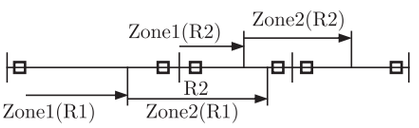
(A) generation of G2 and G3 is increased equally while generation of G1 is unchanged.

(B) generation of G1 alone is increased while generation of G2 and G3 is unchanged.

(C) generation of G1, G2 and G3 is increased equally.

(D) generally of G1, G2 and G3 is increased in the ratio 0.5 : 0.25 : 0.25.

MCQ 1.5.118 Consider the problem of relay co-ordination for the distance relays $R1$ and $R2$ on adjacent lines of a transmission system. The Zone-1 and Zone-2 settings for both the relays are indicated on the diagram. Which of the following indicates the correct time setting for the Zone-2 of relays $R1$ and $R2$.



(A) $TZ2_{R1} = 0.6\,\text{s}, TZ2_{R2} = 0.3\,\text{s}$ (B) $TZ2_{R1} = 0.3\,\text{s}, TZ2_{R2} = 0.6\,\text{s}$

(C) $TZ2_{R1} = 0.3\,\text{s}, TZ2_{R2} = 0.3\,\text{s}$ (D) $TZ2_{R1} = 0.1\,\text{s}, TZ2_{R2} = 0.3\,\text{s}$

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MCQ 1.5.119 A three phase thyristor bridge rectifier is used in a HVDC link. The firing angle α (as measured from the point of natural commutation) is constrained to lie between 5° and 30°. If the dc side current and ac side voltage magnitudes are constant, which of the following statements is true (neglect harmonics in the ac side currents and commutation overlap in your analysis)

(A) Reactive power absorbed by the rectifier is maximum when $\alpha = 5^\circ$

(B) Reactive power absorbed by the rectifier is maximum when $\alpha = 30^\circ$

(C) Reactive power absorbed by the rectifier is maximum when $\alpha = 15^\circ$

(D) Reactive power absorbed by the rectifier is maximum when $\alpha = 15^\circ$

MCQ 1.5.120 A power system consist of 2 areas (area 1 and area 2) connected by a single tie-line. It is required to carry out a load-flow study on this system. While entering the network data, the tie-line data (connectivity and parameters) is inadvertently left out. If the load flow program is run with this incomplete data

(A) The load-flow will converge only if the slack bus is specified in area 1

(B) The load-flow will converge only if the slack bus is specified in area 2

(C) The load-flow will converge if the slack bus is specified in either area 1 or area 2

(D) The load-flow will not converge if only one slack is specified.

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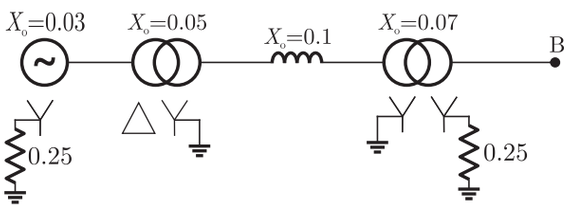
MCQ 1.5.121 A transmission line has a total series reactance of 0.2 pu. Reactive power compensation is applied at the midpoint of the line and it is controlled such that the midpoint voltage of the transmission line is always maintained at 0.98 pu. If voltage at both ends of the line are maintained at 1.0 pu, then the steady state power transfer limit of the transmission line is

(A) 9.8 pu (B) 4.9 pu

(C) 19.6 pu (D) 5 pu

MCQ 1.5.122 A generator is connected to a transformer which feeds another transformer through a short feeder (see figure). The zero sequence impedance values expressed in pu on a common base and are indicated in figure. The Thevenin equivalent zero sequence impedance at point B is



(A) $0.8 + j0.6$ (B) $0.75 + j0.22$

(C) $0.75 + j0.25$ (D) $1.5 + j0.25$

MCQ 1.5.123 *A long lossless transmission line has a unity power factor(UPF) load at the receiving end and an ac voltage source at the sending end. The parameters of the transmission line are as follows :

Characteristic impedance $Z_c = 400\,\Omega$, propagation constant $\beta = 1.2 \times 10^{-3}$ rad/km, and the length $l = 100$ km. The equation relating sending and receiving end questions is

$$V_s = V_r \cos(\beta l) + jZ_c \sin(\beta l) I_R$$

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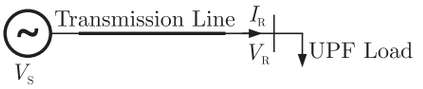
Compute the maximum power that can be transferred to the UPF load at the receiving end if $|V_s| = 230$ kV



MCQ 1.5.124 *Two transposed 3-phase lines run parallel to each other. The equation describing the voltage drop in both lines is given below.

$$\begin{bmatrix}\Delta V_{a1}\\ \Delta V_{b1}\\ \Delta V_{c1}\\ \Delta V_{a2}\\ \Delta V_{b2}\\ \Delta V_{c2}\end{bmatrix} = j\begin{bmatrix}0.15 & 0.05 & 0.05 & 0.04 & 0.04 & 0.04\\ 0.05 & 0.15 & 0.05 & 0.04 & 0.04 & 0.04\\ 0.05 & 0.05 & 0.15 & 0.04 & 0.04 & 0.04\\ 0.04 & 0.04 & 0.04 & 0.15 & 0.05 & 0.05\\ 0.04 & 0.04 & 0.04 & 0.05 & 0.15 & 0.05\\ 0.04 & 0.04 & 0.04 & 0.05 & 0.05 & 0.15\end{bmatrix}\begin{bmatrix}I_{a1}\\ I_{b1}\\ I_{c1}\\ I_{a2}\\ I_{b2}\\ I_{c2}\end{bmatrix}$$

Compute the self and mutual zero sequence impedance of this system i.e. compute $Z_{011}, Z_{012}, Z_{021}, Z_{022}$ in the following equations.

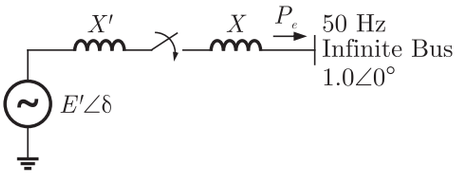
$$\Delta V_{01} = Z_{011}I_{01} + Z_{012}I_{02}$$
$$\Delta V_{02} = Z_{021}I_{01} + Z_{022}I_{02}$$

Where $\Delta V_{01}, \Delta V_{02}, I_{01}, I_{02}$ are the zero sequence voltage drops and currents for the two lines respectively.

MCQ 1.5.125 *A synchronous generator is to be connected to an infinite bus through a transmission line of reactance $X = 0.2$ pu, as shown in figure. The generator data is as follows :

$x' = 0.1$ pu, $E' = 1.0$ pu, $H = 5$ MJ/MVA , mechanical power $P_m = 0.0$ pu, $\omega_B = 2\pi \times 50$ rad/s. All quantities are expressed on a common base.

The generator is initially running on open circuit with the frequency of the open circuit voltage slightly higher than that of the infinite bus. If at the instant of switch closure, $\delta = 0$ and $\omega = \frac{d\delta}{dt} = \omega_{\text{init}}$, compute the maximum value of ω_{init} so that the generator pulls into synchronism.



Hint : Use the equation $\int (2H/\omega_B)\omega d\omega + P_e d\delta = 0$

YEAR 2001 ONE MARK

MCQ 1.5.126 A lossless radial transmission line with surge impedance loading

(A) takes negative VAR at sending end and zero VAR at receiving end

(B) takes positive VAR at sending end and zero VAR at receiving end

(C) has flat voltage profile and unity power factor at all points along it

(D) has sending end voltage higher than receiving end voltage and unity power factor at sending end

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YEAR 2001 TWO MARKS

MCQ 1.5.127 A 3-phase transformer has rating of 20 MVA, 220 kV(star)-33 kV (delta) with leakage reactance of 12%. The transformer reactance (in ohms) referred to each phase of the L.V. delta-connected side is

(A) 23.5 (B) 19.6

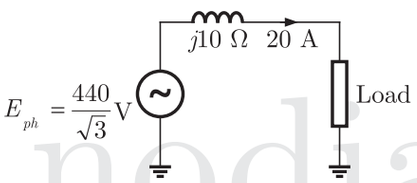
(C) 18.5 (D) 8.7

MCQ 1.5.128 A 75 MVA, 10 kV synchronous generator has $X_d = 0.4$ pu. The X_d value (in pu) to a base of 100 MVA, 11 kV is

(A) 0.578 (B) 0.279

(C) 0.412 (D) 0.44

MCQ 1.5.129 A star-connected 440 V, 50 Hz alternator has per phase synchronous reactance of $10\,\Omega$. It supplies a balanced capacitive load current of 20 A, as shown in the per phase equivalent circuit of figure. It is desirable to have zero voltage regulation. The load power factor would be



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(A) 0.82 (B) 0.47

(C) 0.39 (D) 0.92

MCQ 1.5.130 A 240 V single-phase source is connected to a load with an impedance of $10\angle 60^\circ\,\Omega$. A capacitor is connected in parallel with the load. If the capacitor supplies 1250 VAR, the real power supplied by the source is

(A) 3600 W (B) 2880 W

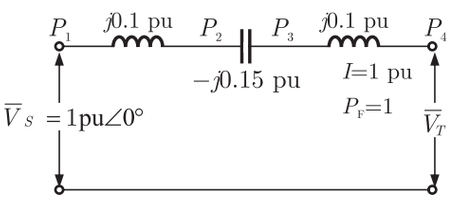
(C) 2400 W (D) 1200 W

MCQ 1.5.131 A 50 Hz alternator is rated 500 MVA, 20 kV, with $X_d = 1.0$ per unit and $X''_d = 0.2$ per unit. It supplies a purely resistive load of 400 MW at 20 kV. The load is connected directly across the generator terminals when a symmetrical fault occurs at the load terminals. The initial rms current in the generator in per unit is

(A) 7.22 (B) 6.4

(C) 3.22 (D) 2.2

MCQ 1.5.132 Consider the model shown in figure of a transmission line with a series capacitor at its mid-point. The maximum voltage on the line is at the location



(A) P_1 (B) P_2

(C) P_3 (D) P_4

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MCQ 1.5.133 A power system has two synchronous generators. The Governor-turbine characteristics corresponding to the generators are

$$P_1 = 50(50 - f), P_2 = 100(51 - f)$$

where f denotes the system frequency in Hz, and P_1 and P_2 are, respectively, the power outputs (in MW) of turbines 1 and 2. Assuming the generators and transmission network to be lossless, the system frequency for a total load of 400 MW is

(A) 47.5 Hz (B) 48.0 Hz

(C) 48.5 Hz (D) 49.0 Hz

MCQ 1.5.134 *A 132 kV transmission line AB is connected to a cable BC. The characteristic impedances of the overhead line and the cable are 400 Ω and 80 Ω respectively. Assume that these are purely resistively. Assume that these are purely resistive. A 250 kV switching surge travels from A to B.

(a) Calculate the value of this voltage surge when it first reaches C

(b) Calculate the value of the reflected component of this surge when the first reflection reaches A.

(c) Calculate the surge current in the cable BC.

MCQ 1.5.135 *For the Y-bus matrix given in per unit values, where the first, second, third, and fourth row refers to bus 1, 2, 3 and 4 respectively, draw the reactance diagram.

$$Y_{\text{Bus}} = j\begin{bmatrix} -6 & 2 & 2.5 & 0 \\ 2 & -10 & 2.5 & 4 \\ 2.5 & 2.5 & -9 & 4 \\ 0 & 4 & 4 & -8 \end{bmatrix}$$

MCQ 1.5.136 *A synchronous generator is connected to an infinite bus through a lossless double circuit transmission line. The generator is delivering 1.0 per unit power at a load angle of 30° when a sudden fault reduces the peak power that can be transmitted to 0.5 per unit. After clearance of fault, the peak power that can be transmitted becomes 1.5 per unit. Find the critical clearing angle.

MCQ 1.5.137 *A single line-to-ground fault occurs on an unloaded generator in phase a positive, negative, and zero sequence impedances of the generator are $j0.25$ pu, $j0.25$ pu, and $j0.15$ pu respectively. The generator neutral is grounded through a reactance of $j0.05$ pu. The prefault generator terminal voltage is 1.0 pu.

(a) Draw the positive, negative, and zero sequence network for the fault given.

(b) Draw the interconnection of the sequence network for the fault analysis.

(c) Determine the fault current

MCQ 1.5.138 A power system has two generators with the following cost curves

Generator1: $C_1(P_{G1}) = 0.006P^2_{G1} + 8P_{G1} + 350$ (Thousand Rupees/Hour)

Generator2: $C_2(P_{G2}) = 0.009P^2_{G2} + 7P_{G2} + 400$ (Thousand Rupees/ Hour)

The generator limits are

$$100 \text{ MW} \le P_{G1} \le 650 \text{ MW}$$

$$50 \text{ MW} \le P_{G2} \le 500 \text{ MW}$$

A load demand of 600 MW is supplied by the generators in an optimal manner. Neglecting losses in the transmission network, determine the optimal generation of each generator.

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SOLUTION

SOL 1.5.1 Option (D) is correct.

SOL 1.5.2 Option (C) is correct.

Consider the voltage phase angles at buses 2 and 3 be Q_2 and Q_3 since, all the three buses have the equal voltage magnitude which is $1\,Pu$ so, it is a D.C. load flow. The injections at Bus 2 and 3 are respectively

$$P_2 = 0.1\,\text{pu}$$
$$P_3 = -0.2\,\text{pu}$$

Therefore, the phase angles are obtained as

$$\begin{bmatrix}\theta_2\\ \theta_3\end{bmatrix} = [B]^{-1}\begin{bmatrix}P_2\\ P_3\end{bmatrix}$$

where $[B]$ is obtained as

$$[B] = \begin{bmatrix}\frac{1}{X_{12}}+\frac{1}{X_{23}} & \frac{1}{X_{23}}\\ \frac{-1}{X_{23}} & \frac{1}{X_{23}}+\frac{1}{X_{13}}\end{bmatrix}$$
$$= \begin{bmatrix}1+1 & -1\\ -1 & 1+1\end{bmatrix} = \begin{bmatrix}2 & -1\\ -1 & 2\end{bmatrix}$$

Its inverse is obtained as

$$[B]^{-1} = \begin{bmatrix}2 & -1\\ 1- & 2\end{bmatrix}^{-1}$$
$$= \frac{1}{3}\begin{bmatrix}2 & 1\\ +1 & 2\end{bmatrix}\begin{bmatrix}0.1\\ -0.2\end{bmatrix}$$

Therefore,

$$\begin{bmatrix}\theta_2\\ \theta_3\end{bmatrix} = \frac{1}{3}\begin{bmatrix}2 & 1\\ +1 & 2\end{bmatrix}\begin{bmatrix}0.1\\ -0.2\end{bmatrix}$$
$$= \frac{1}{3}\begin{bmatrix}0\\ -0.3\end{bmatrix}$$
$$= \begin{bmatrix}0\\ -0.1\end{bmatrix}$$

i.e., $\theta_2 = 0$

and $\theta_3 = -0.1\,\text{rad}$

SOL 1.5.3 Option (C) is correct.

From the above solution, we have

$$P_2 = 0.1$$
$$P_3 = -0.2$$

since,

$$P_1 + P_2 + P_3 = 0 \text{ (Where } P_1 \text{ is injection at bus 1)}$$

So, $P_1 - P_2 - P_3 = -0.1 + 0.2 = 0.1\,\text{pu}$

Now, the apparent power delivered to base is

$$|S| = \frac{V^2}{R} = \frac{(100\times 10^3)^2}{100}$$
$$= 100\times 10^6\,\text{VA}$$

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Therefore, the real power delivered by slack bus (bus 1)

$$\begin{aligned} P &= P_1|S| = (0.1) \times 100 \times 10^6 \\ &= 10 \times 10^6 \text{ watt} \\ &= 10 \text{ MW} \end{aligned}$$

SOL 1.5.4 Option (B) is correct.

For bus admittance matrix,

$$\begin{aligned} Y_{11} + (Y_{12} + y_{line}) + Y_{13} &= 0 \\ -j13 + (j10 + y_{line}) + j5 &= 0 \\ y_{line} &= -j2 \end{aligned}$$

Magnitude of susceptance is $+2$

SOL 1.5.5 Option (A) is correct.

$$\begin{aligned} i_1(t) &= I_m \sin(\omega t - \phi_1) \\ i_2(t) &= I_m \cos(\omega t - \phi_2) \end{aligned}$$

We know that,

$$\cos(\theta - 90^\circ) = \sin\theta$$

So, $i_1(t)$ can be written as

$$\begin{aligned} i_1(t) &= I_m \cos(\omega t - \phi_1 - 90^\circ) \\ i_2(t) &= I_m \cos(\omega t - \phi_2) \end{aligned}$$

Now, in phasor form

$$\begin{aligned} I_1 &= I_m \angle \phi_1 + 90^\circ \\ I_2 &= I_m \angle \phi_2 \end{aligned}$$

Current are balanced if $I_1 + I_2 = 0$

$$\begin{aligned} I_m \angle \phi_1 + 90^\circ + I_m \angle \phi_2 &= 0 \\ I_m \cos(\phi_1 + 90^\circ) + jI_m \sin(\phi_1 + 90^\circ) + \cos\phi_2 + j\sin\phi_2 &= 0 \\ I_m\left[\cos(\phi_1 + 90^\circ) + j\sin(\phi_1 + 90^\circ)\right] + I_m\left[\cos\phi_2 + j\sin\phi_2\right] &= 0 \\ I_m\left[\cos(\phi_1 + 90^\circ) + \cos\phi_2\right] + jI_m\left[\sin\phi_2 + \sin(\phi_1 + 90^\circ)\right] &= 0 \\ \cos(\phi_1 + 90^\circ) + \cos\phi_2 &= 0 \\ \cos(\phi_1 + 90^\circ) &= -\cos\phi_2 = \cos(\pi + \phi_2) \\ \phi_1 + 90^\circ &= \pi + \phi_2 \end{aligned}$$

or,

$$\phi_1 = \frac{\pi}{2} + \phi_2$$

SOL 1.5.6 Option (A) is correct.

Let penalty factor of plant G, is L_1 given as

$$L_1 = \frac{1}{1 - \dfrac{\partial P_L}{\partial P_{G_1}}}$$

$$\begin{aligned} P_L &= 0.5P_{G_1}^2 \\ \frac{\partial P_L}{\partial P_{G_2}} &= 0.5(2P_{G_1}) = P_{G_1} \end{aligned}$$

So,

$$L_1 = \frac{1}{1 - P_{G_2}}$$

Penalty factor of plant G_2 is

$$L_2 = \frac{1}{1 - \dfrac{\partial P_L}{\partial P_{G_2}}} = 1 \qquad \left(\because \ \frac{\partial P_L}{\partial P_{G_2}} = 0\right)$$

For economic power generation

$$C_1 \times L_1 = C_2 \times L_2$$

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where C_1 and C_2 are the incremental fuel cost of plant G_1 and G_2.

So, $(10000)\left(\frac{1}{1-P_{G_2}}\right) = 12500 \times 1$

$$\frac{4}{5} = 1 - P_{G_2}$$

$$P_{G_2} = \frac{1}{5}\,\text{pu}$$

It is an 100 MVA, so $P_{G_2} = \frac{1}{5} \times 100 = 20\,\text{MW}$

Loss $P_L = 0.5\left(\frac{1}{5}\right)^2 = \frac{1}{50}\,\text{pu}$

or $P_L = \frac{1}{50} \times 100 = 2\,\text{MW}$

Total power, $P_L = P_{G_1} + P_{G_2} - P_L$

$$40 = 20 + P_2 - 2$$

$$P_{G_2} = 22\,\text{MW}$$

SOL 1.5.7 Option (C) is correct.

For double line-to-ground (LLG) fault, relation between sequence current is

$$I_{\text{positive}} = -(I_{\text{negative}} + I_{\text{zero}})$$

Gives values satisfy this relation, therefore the type of fault is LLG.

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SOL 1.5.8 Option (B) is correct.

Complex power for generator

$$S_{G_1} = S_{D1} + S_{D2} = 1 + 1 = 2\,\text{pu} \qquad \text{(Line is lossless)}$$

Power transferred from bus 1 to bus 2 is 1 pu, so

$$1 = \frac{|V_1||V_2|\sin(\theta_1 - \theta_2)}{X}$$

$$= \frac{1 \times 1}{0.5}\sin(\theta_1 - \theta_2) \qquad |V_1| = |V_2| = 1\,\text{pu},\ X = 0.5\,\text{pu}$$

$$0.5 = \sin(\theta_1 - \theta_2)$$

$$\theta_1 - \theta_2 = 30^\circ$$

$$\theta_2 = \theta_1 - 30^\circ = -30^\circ \qquad (\theta_1 = 0^\circ)$$

So, $V_1 = 1\angle 0^\circ\ \text{V}$

$$V_2 = 1\angle -30^\circ\ \text{V}$$

Current, $I_{12} = \frac{V_1 - V_2}{Z} = \frac{1\angle 0^\circ - 1\angle 30^\circ}{j0.5} = (1 - j0.288)\,\text{pu}$

Current in S_{D_2} is I_2, $S_{D_2} = V_2 I_2^*$

$$1 = 1\angle -30^\circ I_2^*$$

$$I_2 = 1\angle -30^\circ\ \text{pu}$$

Current in Q_{G_2}, $I_G = I_2 - I_{12} = 1\angle -30^\circ - (1 - j0.288)$

$$= 0.268\angle -120^\circ$$

VAR rating of capacitor,

$$Q_C = |V_2||V_G| = 1 \times 0.268 = 0.268\,\text{pu}$$

SOL 1.5.9 Option (D) is correct.

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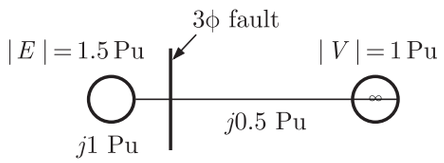

Total reactance, $X = j1 + j0.5 = j1.5\ \text{pu}$

Critical angle is given as,

$$\delta_{cr} = \cos^{-1}[(\pi - 2\delta_0)\sin\delta_0 - \cos\delta_0] \qquad ...(i)$$

$\delta_0 \rightarrow$ steady state torque angle.

Steady state power is given as

$$P_m = P_{\max}\sin\delta_0$$

where, $$P_{\max} = \frac{|E||V|}{|X|}$$

So, $$P_m = \frac{|E||V|}{|X|}\sin\delta_0$$

$$0.5 = \frac{(1.5)(1)}{1.5}\sin\delta_0 \qquad P_m = 0.5\ \text{pu}$$

$$\sin\delta_0 = 0.5$$

$$\delta_0 = 30^\circ$$

In radian, $$\delta_0 = 30^\circ \times \frac{\pi}{180^\circ} = 0.523$$

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Substituting δ_0 into equation (i)

$$\delta_{cr} = \cos^{-1}[(\pi - 2 \times 0.523)\sin 30^\circ - \cos 30^\circ]$$
$$= \cos^{-1}[(2.095)(0.5) - 0.866]$$
$$= \cos^{-1}(0.1815) \simeq 79.6^\circ$$

SOL 1.5.10 Option ( ) is correct

SOL 1.5.11 Option (A) is correct.

Negative phase sequence relay is used for the protection of alternators against unbalanced loading that may arise due to phase-to-phase faults.

SOL 1.5.12 Option (C) is correct.

Steady state stability or power transfer capability

$$P_{\max} = \frac{|E||V|}{X}$$

To improve steady state limit, reactance X should be reduced. The stability may be increased by using two parallel lines. Series capacitor can also be used to get a better regulation and to increase the stability limit by decreasing reactance.

Hence (C) is correct option.

SOL 1.5.13 Option (A) is correct.

We know that

$$loss \propto P_G^2$$

$$loss \propto \text{length}$$

Distance of load from G_1 is 25 km Distance of load from G_2 & G_3 is 75 km generally we supply load from nearest generator. So maximum of load should be supplied from G_1. But G_2 & G_3 should be operated at same minimum generation.

SOL 1.5.14 Option (B) is correct.

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Power angle for salient pole alternator is given by

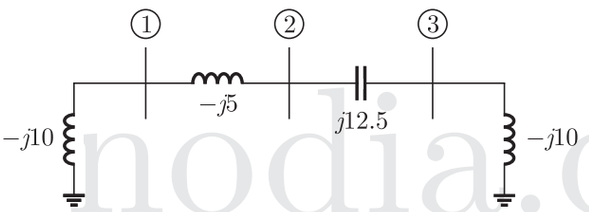
$$\tan\delta = \frac{V_t \sin\phi + I_a X_q}{V_t \cos\phi + I_a R_a}$$

Since the alternator is delivering at rated kVA rated voltage

$$\begin{aligned} I_a &= 1\,\text{pu} \\ V_t &= 1\,\text{pu} \\ \phi &= 0^\circ \\ \sin\phi &= 0, \quad \cos\phi = 1 \\ X_q &= 1\,\text{pu}, \quad X_d = 1.2\,\text{pu} \\ \tan\delta &= \frac{1\times 0 + 1(1)}{1+0} \\ &= 1 \\ \delta &= 45^\circ \end{aligned}$$

SOL 1.5.15 Option (B) is correct.

The admittance diagram is shown below



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here

$$y_{10} = -10j, \quad y_{12} = -5j, \quad y_{23} = 12.5j, \quad y_{30} = -10j$$

Note: y_{23} is taken positive because it is capacitive.

$$\begin{aligned} Y_{11} &= y_{10} + y_{12} = -10j - 5j = -15j \\ Y_{12} &= Y_{21} = -y_{21} = 5j \\ Y_{13} &= Y_{31} = -y_{13} = 0 \\ Y_{22} &= y_{20} + y_{21} + y_{23} = 0 + (-5j) + (12.5j) = 7.5j \\ Y_{23} &= Y_{32} = -y_{23} = -12.5j \\ Y_{33} &= y_{30} + y_{13} + y_{23} = -10j + 0 + 12.5j = 2.5j \end{aligned}$$

So the admittance matrix is

$$Y = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{33} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix} = \begin{bmatrix} -15j & 5j & 0 \\ 5j & 7.5j & -12.5j \\ 0 & -12.5j & 2.5j \end{bmatrix}$$

SOL 1.5.16 Option (A) is correct.

For generator G_1

$$X''_{G_1} = 0.25 \times \frac{100}{250} = 0.1\,\text{pu}$$

For generator G_2

$$X''_{G_1} = 0.10 \times \frac{100}{100} = 0.1\,\text{pu}$$

$$X_{L_2} = X_{L_1} = 0.225 \times 10 = 2.25\,\Omega$$

For transmission lines L_1 and L_2

$$Z_{\text{base}} = \frac{kV^2_{\text{base}}}{MVA_{\text{base}}} = \frac{15\times 15}{100} = 2.25\,\Omega$$

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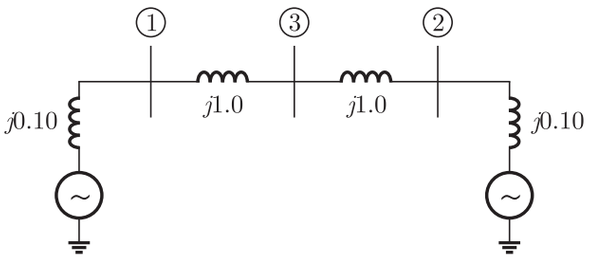
$$X''_{L_2}(\text{pu}) = \frac{2.25}{2.25} = 1\,\text{pu}$$

$$X''_{L_1}(\text{pu}) = \frac{2.25}{2.25} = 1\,\text{pu}$$

So the equivalent pu reactance diagram



SOL 1.5.17 Option (D) is correct.

We can see that at the bus 3, equivalent thevenin's impedance is given by

$$X_{th} = (j0.1 + j1.0)\,||\,(j0.1 + j1.0) = j1.1\,||\,j1.1 = j0.55\,\text{pu}$$

$$\text{Fault MVA} = \frac{\text{Base MVA}}{X_{th}} = \frac{100}{0.55} = 181.82\,\text{MVA}$$

SOL 1.5.18 Option (C) is correct.

Given that,

$$I > 0$$

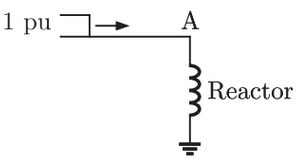
$\because$ $V_{AB} > 0$ since it is Rectifier O/P

$V_{CD} > 0$ since it is Inverter I/P

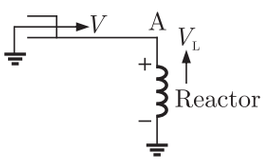
$\because I > 0$ so $V_{AB} > V_{CD}$, Than current will flow in given direction.

SOL 1.5.19 Option (A) is correct.

Given step voltage travel along lossless transmission line.



$\because$ Voltage wave terminated at reactor as.



By Applying KVL

$$V + V_L = 0$$

$$V_L = -V$$

$$V_L = -1\ \text{pu}$$

SOL 1.5.20 Option (A) is correct.

Given two buses connected by an Impedance of $(0 + j5)\,\Omega$

The Bus '1' voltage is $100\angle 30^\circ$ V and Bus '2' voltage is $100\angle 0^\circ$ V

We have to calculate real and reactive power supply by bus '1'

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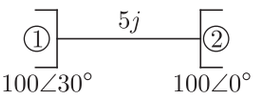


$$P + jQ = VI^* = 100\angle 30^\circ\left[\frac{100\angle 30^\circ - 100\angle 0^\circ}{5j}\right]$$
$$= 100\angle 30^\circ\,[20\angle -60^\circ - 20\angle -90^\circ]$$
$$= 2000\angle -30^\circ - 2000\angle -60^\circ$$
$$P + jQ = 1035\angle 15^\circ$$

real power $P = 1035\cos 15^\circ = 1000$ W

reactive power $Q = 1035\sin 15^\circ = 268$ VAR

SOL 1.5.21 Option (C) is correct.

Given 3-ϕ, 33 kV oil circuit breaker.

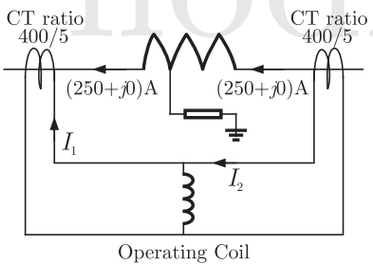
Rating 1200 A, 2000 MVA, 3 sec

Symmetrical breaking current $I_b = ?$

$$I_b = \frac{MVA}{\sqrt{3}\text{ kV}}\text{kA} = \frac{2000}{\sqrt{3}\times 33} = 34.99\text{ kA} \simeq 35\text{ kA}$$

SOL 1.5.22 Option (C) is correct.

Given a stator winding of an alternator with high internal resistance fault as shown in figure



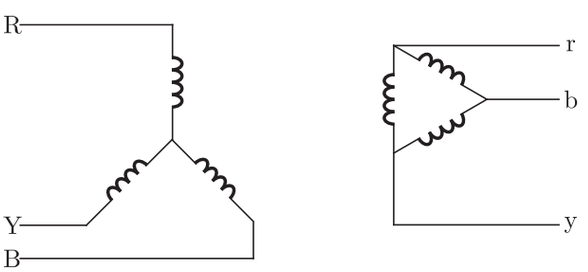
Current through operating coil

$$I_1 = 220\times\frac{5}{400}\text{ A},\ I_2 = 250\times\frac{5}{400}\text{ A}$$

Operating coil current $= I_2 - I_1 = (250-220)\times 5/400 = 0.375$ Amp

SOL 1.5.23 Option (C) is correct.

Zero sequence circuit of 3-ϕ transformer shown in figure is as following:



No option seems to be appropriate but (C) is the nearest.

SOL 1.5.24 Option (D) is correct.

Given that

A 50 Hz Generator is initially connected to a long lossless transmission line which is open circuited as receiving end as shown in figure.

Due to ferranti effect the magnitude of terminal voltage does not change, and the

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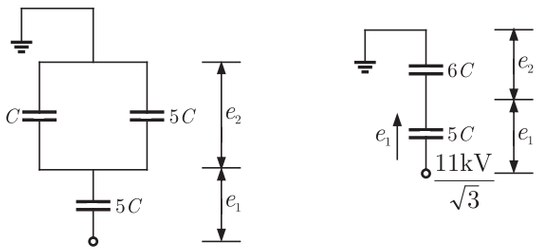
field current decreases.

SOL 1.5.25 Option (B) is correct.

Given : 3-ϕ, 50 Hz, 11 kV distribution system, We have to find out $e_1, e_2 = ?$

Equivalent circuit is as following



$$e_1 = \frac{\frac{11}{\sqrt{3}}(6C)}{6C+5C} = \frac{11}{\sqrt{3}} \times \frac{6}{11} = 3.46 \text{ kV}$$

$$e_2 = \frac{11}{\sqrt{3}} \times \frac{5}{11} = 2.89 \text{ kV}$$

SOL 1.5.26 Option (A) is correct.

Given : 3-ϕ, 50 Hz, 11 kV cable

$$C_1 = 0.2\,\mu\text{F}$$
$$C_2 = 0.4\,\mu\text{F}$$

Charging current I_C per phase $= ?$

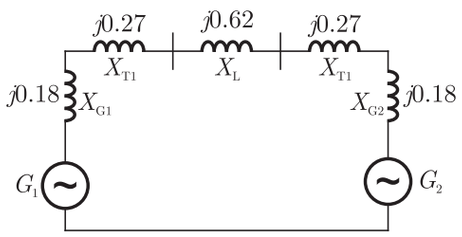
$$\text{Capacitance Per Phase } C = 3C_1 + C_2$$
$$C = 3 \times 0.2 + 0.4 = 1\,\mu\text{F}$$
$$\omega = 2\pi f = 314$$
$$\text{Changing current } I_C = \frac{V}{X_C} = V(\omega C) = \frac{11 \times 10^3}{\sqrt{3}} \times 314 \times 1 \times 10^{-6}$$
$$= 2 \text{ Amp}$$

SOL 1.5.27 Option (B) is correct.

Generator G_1 and G_2

$$X_{G1} = X_{G2} = X_{\text{old}} \times \frac{\text{New MVA}}{\text{Old MVA}} \times \left(\frac{\text{Old kV}}{\text{New kV}}\right)^2$$
$$= j0.9 \times \frac{200}{100} \times \left(\frac{25}{25}\right)^2 = j0.18$$
$$\text{Same as } X_{T1} = j0.12 \times \frac{200}{90} \times \left(\frac{25}{25}\right)^2 = j0.27$$
$$X_{T2} = j0.12 \times \frac{200}{90} \times \left(\frac{25}{25}\right)^2 = j0.27$$
$$X_{\text{Line}} = 150 \times \frac{220}{(220)^2} = j0.62$$

The Impedance diagram is being given by as



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SOL 1.5.28 Option ( ) is correct.

SOL 1.5.29 Option (C) is correct.

We know complex power

$$S = P + jQ = VI(\cos\phi + j\sin\phi) = VIe^{j\phi}$$

$$I = \frac{S}{Ve^{j\phi}}$$

$\because$ Real Power loss $= I^2R$

$$P_L = \left(\frac{S}{Ve^{j\phi}}\right)^2 R = \frac{S^2R}{e^{j2\phi}} \times \frac{1}{V^2} \qquad \because \frac{S^2R}{e^{j2\phi}} = \text{Constant}$$

So $$P_L \propto \frac{1}{V^2}$$

SOL 1.5.30 Option (C) is correct.

Y_{Bus} matrix of Y-Bus system are given as

$$Y_{\text{Bus}} = j\begin{bmatrix} -5 & 2 & 2.5 & 0 \\ 2 & -10 & 2.5 & 0 \\ 2.5 & 2.5 & -9 & 4 \\ 0 & 4 & 4 & -8 \end{bmatrix}$$

We have to find out the buses having shunt element

We know $$Y_{\text{Bus}} = \begin{bmatrix} y_{11} & y_{12} & y_{13} & y_{14} \\ y_{21} & y_{22} & y_{23} & y_{24} \\ y_{31} & y_{32} & y_{33} & y_{34} \\ y_{41} & y_{42} & y_{43} & y_{44} \end{bmatrix}$$

Here

$$y_{11} = y_{10} + y_{12} + y_{13} + y_{14} = -5j$$
$$y_{22} = y_{20} + y_{21} + y_{23} + y_{24} = -10j$$
$$y_{33} = y_{30} + y_{31} + y_{32} + y_{34} = -9j$$
$$y_{44} = y_{40} + y_{41} + y_{42} + y_{43} = -8j$$
$$y_{12} = y_{21} = -y_{12} = 2j$$
$$y_{13} = y_{31} = -y_{13} = 2.5j$$
$$y_{14} = y_{41} = -y_{14} = 0j$$
$$y_{23} = y_{32} = -y_{23} = 2.5j$$
$$y_{24} = y_{42} = -y_{24} = 4j$$

So

$$y_{10} = y_{11} - y_{12} - y_{13} - y_{14} = -5j + 2j + 2.5j + 0j = -0.5j$$
$$y_{20} = y_{22} - y_{12} - y_{23} - y_{24} = -10j + 2j + 2.5j + 4j = -1.5j$$
$$y_{30} = y_{33} - y_{31} - y_{32} - y_{34} = -9j + 2.5j + 2.5j + 4j = 0$$
$$y_{40} = y_{44} - y_{41} - y_{42} - y_{43} = -8j - 0 + 4j + 4j = 0$$

Admittance diagram is being made by as

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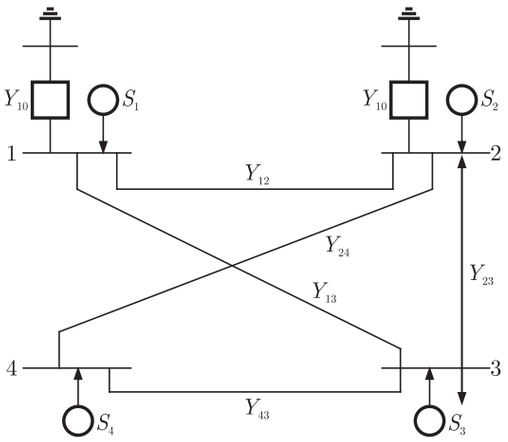

From figure. it is cleared that branch (1) & (2) behaves like shunt element.

SOL 1.5.31 Option (B) is correct.

We know that

- Shunt Capacitors are used for improving power factor.
- Series Reactors are used to reduce the current ripples.
- For increasing the power flow in line we use series capacitor.
- Shunt reactors are used to reduce the Ferranti effect.

SOL 1.5.32 Option (C) is correct.

We know that for different type of transmission line different type of distance relays are used which are as follows.

Short Transmission line -Ohm reactance used

Medium Transmission Line -Reactance relay is used

Long Transmission line -Mho relay is used

SOL 1.5.33 Option (C) is correct.

Given that three generators are feeding a load of 100 MW. For increased load power demand, Generator having better regulation share More power, so Generator -1 will share More power than Generator -2.

SOL 1.5.34 Option (A) is correct.

Given Synchronous generator of 500 MW, 21 kV, 50 Hz, 3-ϕ, 2-pole

P.F = 0.9, Moment of inertia $M = 27.5 \times 10^3$ kg-m^2

Inertia constant H = ?

$$\text{Generator rating in MVA } G = \frac{P}{\cos\phi} = \frac{500\,\text{MW}}{0.9} = 555.56\,\text{MVA}$$

$$N = \frac{120 \times \text{f}}{\text{pole}} = \frac{120 \times 50}{2} = 3000 \text{ rpm}$$

$$\text{Stored K.E} = \frac{1}{2}M\omega^2 = \frac{1}{2}M\left(\frac{2\pi N}{60}\right)^2$$

$$= \frac{1}{2} \times 27.5 \times 10^3 \times \left(\frac{2\pi \times 3000}{60}\right)\text{MJ}$$

$$= 1357.07\,\text{MJ}$$

$$\text{Inertia constant } (H) = \frac{\text{Stored K.E}}{\text{Rating of Generator (MVA)}}$$

$$H = \frac{1357.07}{555.56}$$

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$$= 2.44 \text{ sec}$$

SOL 1.5.35 Option (D) is correct.

Given for X to F section of phase 'a'

V_a-Phase voltage and I_a-phase current.

Impedance measured by ground distance,

$$\text{Relay at X} = \frac{\text{Bus voltage}}{\text{Current from phase 'a'}} = \frac{V_a}{I_a}\,\Omega$$

SOL 1.5.36 Option (D) is correct.

For EHV line given data is

Length of line = 300 km and $\beta = 0.00127$S rad/km

$$\text{wavelength } \lambda = \frac{2\pi}{\beta} = \frac{2\pi}{0.00127} = 4947.39 \text{ km}$$

So
$$\frac{l}{\lambda}\% = \frac{300}{4947.39} \times 100 = 0.06063 \times 100$$

$$\frac{l}{\lambda}\% = 6.063$$

SOL 1.5.37 Option (B) is correct.

For three phase transmission line by solving the given equation

We get,
$$\begin{bmatrix}\Delta V_a\\ \Delta V_b\\ \Delta V_c\end{bmatrix} = \begin{bmatrix}(X_s - X_m) & 0 & 0\\ 0 & (X_s - X_m) & 0\\ 0 & 0 & (X_s + 2X_m)\end{bmatrix}\begin{bmatrix}I_a\\ I_b\\ I_c\end{bmatrix}$$

$$\text{Zero sequence Impedance} = X_s + 2X_m = 48 \quad \ldots(1)$$

$$\text{and Positive Sequence Impedance} = \text{Negative Sequence Impedance}$$
$$= (X_s - X_m)$$
$$= 15 \quad \ldots(2)$$

By solving equation (1) and (2)

$$Z_s \text{ or } X_s = 26 \text{ and } Z_m \text{ or } X_m = 11$$

SOL 1.5.38 Option ( ) is correct.

SOL 1.5.39 Option (B) is correct.

SIL has no effect of compensation

So SIL = 2280 MW

SOL 1.5.40 Option (C) is correct.

Given $P_{G1} + P_{G2} = 250$ MW ...(1)

and
$$\left.\begin{aligned} C_1(P_{G1}) &= P_{G1} + 0.055P_{G1}^2\\ C_2(P_{G2}) &= 3P_{G2} + 0.03P_{G2}^2\end{aligned}\right\} \quad \ldots(2)$$

from equation (2)

$$\frac{dC_1}{dP_{G1}} = 1 + 0.11P_{G1} \quad \ldots(3a)$$

and
$$\frac{dC_2}{dP_{G2}} = 3 + 0.06P_{G2} \quad \ldots(3b)$$

Since the system is loss-less

Therefore
$$\frac{dC_1}{dP_{G1}} = \frac{dC_2}{dP_{G2}}$$

So from equations (3a) and (3b)

We have $0.11P_{G1} - 0.06P_{G2} = 2$ ...(4)

Now solving equation (1) and (4), we get

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$$P_{G1} = 100 \text{ MW}$$
$$P_{G2} = 150 \text{ MW}$$

SOL 1.5.41 Option (B) is correct.

After connecting both the generators in parallel and scheduled to supply 0.5 Pu of power results the increase in the current.

$\therefore$ Critical clearing time will reduced from 0.28 s but will not be less than 0.14 s for transient stability purpose.

SOL 1.5.42 Option (D) is correct.

Given that the each section has equal impedance.

Let it be R or Z, then by using the formula

$$\text{line losses} = \sum I^2 R$$
$$\text{On removing } (e_1); \text{ losses} = (1)^2 R + (1+2)^2 R + (1+2+5)^2 R$$
$$= R + 9R + 64R = 74R$$

Similarly,

$$\text{On removing } e_2; \text{losses} = 5^2 R + (5+2)^2 R + (5+2+1)^2 R = 138R$$
$$\text{lossess on removing } e_3 = (1)^2 R + (2)^2 R + (5+2)^2 R$$
$$= 1R + 4R + 49R = 54R$$
$$\text{on removing } e_4 \text{ lossless} = (2)^2 R + (2+1)^2 R + 5^2 R$$
$$= 4R + 9R + 25R = 38R$$

So, minimum losses are gained by removing e_4 branch.

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SOL 1.5.43 Option (A) is correct.

Given : $V(t) = V_m \cos(\omega t)$

For symmetrical $3-\phi$ fault, current after the fault

$$i(t) = Ae^{-(R/L)t} + \frac{\sqrt{2}\,V_m}{|Z|}\cos(\omega t - \alpha)$$

At the instant of fault i.e $t = t_0$, the total current $i(t) = 0$

$$\therefore \quad 0 = Ae^{-(R/L)t_0} + \frac{\sqrt{2}\,V_m}{|Z|}\cos(\omega t_0 - \alpha)$$

$$Ae^{-(R/L)t_0} = -\frac{\sqrt{2}\,V_m}{|Z|}\cos(\omega t_0 - \alpha)$$

Maximum value of the dc offset current

$$Ae^{-(R/L)t_0} = -\frac{\sqrt{2}\,V_m}{|Z|}\cos(\omega t_0 - \alpha)$$

For this to be negative max.

$$(\omega t_0 - \alpha) = 0$$

or
$$t_0 = \frac{\alpha}{\omega} \qquad \ldots(1)$$

and
$$Z = 0.004 + j0.04$$
$$Z = |Z| \angle \alpha = 0.0401995 \angle 84.29^\circ$$
$$\alpha = 84.29^\circ \text{or } 1.471 \text{ rad.}$$

From equation (1)

$$t_0 = \frac{1.471}{(2\pi \times 50)} = 0.00468 \text{ sec}$$
$$t_0 = 4.682 \text{ ms}$$

SOL 1.5.44 Option (C) is correct.

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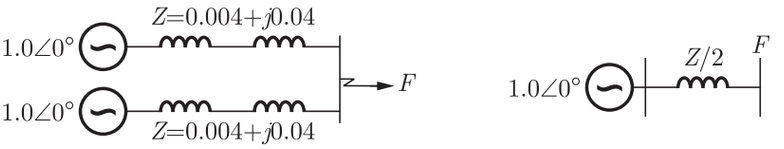
Since the fault 'F' is at mid point of the system, therefore impedance seen is same from both sides.



$$\frac{Z}{2} = 0.0201 \angle 84.29^\circ$$

$$Z_1(\text{Positive sequence}) = \frac{Z}{2} = 0.0201 \angle 84.29^\circ$$

also $Z_1 = Z_2 = Z_0$ (for 3-ϕ fault)

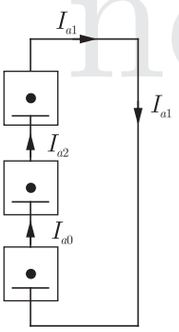
$$\therefore \qquad I_f(\text{pu}) = \frac{1 \angle 0^\circ}{Z_1} = \frac{1 \angle 0^\circ}{0.0201 \angle 84.29^\circ}$$

So magnitude $\quad |I_f|_{(\text{p.u.})} = 49.8$

$$\therefore \text{ Fault current} \qquad I_f = 49.8 \times \frac{100}{\sqrt{3} \times 400} = 7.18 \text{ kA}$$

SOL 1.5.45 Option (A) is correct.

If fault is LG in phase 'a'



$$Z_1 = \frac{Z}{2} = 0.0201 \angle 84.29^\circ$$

$$Z_2 = Z_1 = 0.0201 \angle 84.29^\circ$$

and $\qquad Z_0 = 3Z_1 = 0.0603 \angle 84.29^\circ$

Then $\qquad I_a/3 = I_{a1} = I_{a2} = I_{a0}$

$$I_{a1}(p\text{u}) = \frac{1.0 \angle 0^\circ}{Z_1 + Z_2 + Z_0}$$

and $\qquad |I_{a1}| = \dfrac{1.0}{(0.0201 + 0.0201 + 0.0603)} = 9.95 \text{ pu}$

Fault Current $I_f = I_a = 3I_{a1} = 29.85$ pu

So Fault current $I_f = 29.85 \times \dfrac{100}{\sqrt{3} \times 400} = 4.97$ kA

SOL 1.5.46 Option (A) is correct.

$\because$ Equal Phase shift of point A & B with respect to source from both bus paths. So the type of transformer Y-Y with angle 0°.

SOL 1.5.47 Option (C) is correct.

Given incremental cost curve

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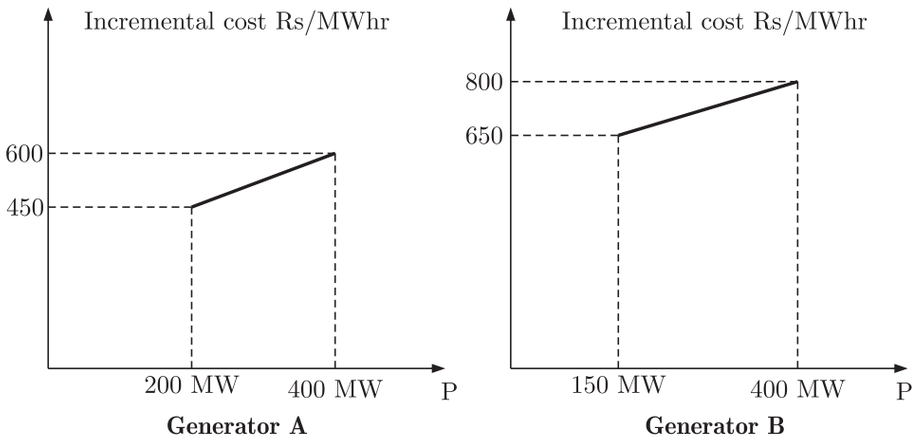

$$P_A + P_B = 700 \text{ MW}$$

For optimum generator $P_A = ?$, $P_B = ?$

From curve, maximum incremental cost for generator A

$$= 600 \text{ at } 450 \text{ MW}$$

and maximum incremental cost for generator B

$$= 800 \text{ at } 400 \text{ MW}$$

minimum incremental cost for generator B

$$= 650 \text{ at } 150 \text{ MW}$$

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Maximim incremental cost of generation A is less than the minimum incremental constant of generator B. So generator A operate at its maximum load = 450 MW for optimum generation.

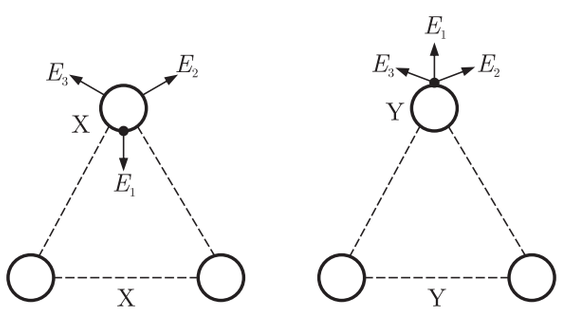
$$P_A = 450 \text{ MW}$$
$$P_B = (700 - 450)$$
$$= 250 \text{ MW}$$

SOL 1.5.48 Option (C) is correct.

Here power sharing between the AC line and HVDC link can be changed by controlling the HVDC converter alone because before changing only grid angle we can change the power sharing between the AC line and HVDC link.

SOL 1.5.49 Option (B) is correct.

We have to find out maximum electric field intensity at various points. Electric field intensity is being given by as follows



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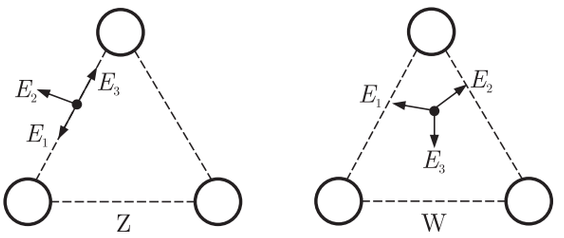

From figures it is cleared that at point Y there is minimum chances of cancelation. So maximum electric field intensity is at point Y.

SOL 1.5.50 Option (D) is correct.
To increase capacitive dc voltage slowly to a new steady state value first we have to make $\delta = -$ ve than we have to reach its original value.

SOL 1.5.51 Option (B) is correct.
Given that

$$\text{Reactance of line} = 0.045 \text{ pu} \Rightarrow L = \frac{.045}{2\pi \times 50}$$

$$\text{Suspectance of Line} = 1.2 \text{ pu} \Rightarrow C = \frac{1}{2\pi \times 50} \times \frac{1}{1.2}$$

$$\text{Velocity of wave propagation} = 3 \times 10^5 \text{ Km/sec}$$

$$\text{Length of line } l = ?$$

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We know velocity of wave propagation

$$V_X = \frac{l}{\sqrt{LC}}$$

$$l = V_X \sqrt{LC} = 3 \times 10^5 \sqrt{\frac{.45}{2\pi \times 50} \times \frac{1}{2\pi \times 50} \times \frac{1}{1.2}}$$

$$= 185 \text{ Km}$$

SOL 1.5.52 Option (C) is correct.
Due to the fault 'F' at the mid point and the failure of circuit-breaker '4' the sequence of circuit-breaker operation will be
5, 6, 7, 3, 1, 2 (as given in options)
(due to the fault in the particular zone, relay of that particular zone must operate first to break the circuit, then the back-up protection applied if any failure occurs.)

SOL 1.5.53 Option (A) is correct.

$$R = [V_{an}\, V_{bn}\, V_{cn}] \begin{bmatrix} 0 & \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} \\ -\frac{1}{\sqrt{3}} & 0 & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} & 0 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

By solving we get

$$R = \left[\frac{V_{an}}{\sqrt{3}}(i_b - i_c) + \frac{V_{bn}}{\sqrt{3}}(i_c - i_a) + \frac{V_c}{\sqrt{3}}(i_a - i_b)\right]$$

$$R = 3(VI) \text{ , where } \frac{(i_b - i_c)}{\sqrt{3}} = I \text{ and } V_{an} = V$$

SOL 1.5.54 Option (C) is correct.

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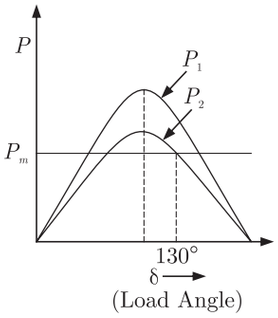

Here $P_1 \rightarrow$ power before the tripping of one ckt

$P_2 \rightarrow$ Power after tripping of one ckt

$$P = \frac{EV}{X}\sin\delta$$

Since $$P_{\max} = \frac{EV}{X}$$

$$\therefore \quad P_{2\max} = \frac{EX}{X_2}, \qquad \text{here, } [X_2 = (0.1 + X)\,(\text{pu})]$$

To find maximum value of X for which system does not loose synchronism

$$P_2 = P_m \text{ (shown in above figure)}$$

$$\therefore \quad \frac{EV}{X_2}\sin\delta_2 = P_m$$

as $P_m = 1\,\text{pu}, E = 1.0\,\text{pu}, V = 1.0\,\text{pu}$

$$\frac{1.0 \times 1.0}{X_2}\sin 130^\circ = 1$$

$$\Rightarrow \quad X_2 = 0.77$$

$$\Rightarrow \quad (0.1 + X) = 0.77$$

$$\Rightarrow \quad X = 0.67$$

SOL 1.5.55 Option (B) is correct.

Given that

$$F_P = KAF_S \qquad \ldots(1)$$

where, Phase component $F_P = \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix}$, sequence component $F_S = \begin{bmatrix} f_p \\ f_n \\ f_o \end{bmatrix}$

and $$A = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix}$$

$$\therefore \quad \left.\begin{aligned} V_P &= KAV_S \\ I_P &= KAI_S \end{aligned}\right\} \qquad \ldots(2)$$

and $$V_S = Z'[I_S] \qquad \ldots(3)$$

where $$Z' = \begin{bmatrix} 0.5 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 2.0 \end{bmatrix}$$

We have to find out Z if $V_P = ZI_P$ $\qquad \ldots(4)$

From equation (2) and (3)

$$V_P = KAZ'[I_S]$$

$$V_P = KAZ'\left(\frac{A^{-1}}{K}\right)I_p$$

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$$V_P = AZ'A^{-1}I_p \quad \ldots(5)$$

$$A = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix}$$

$$A^{-1} = \frac{\text{Adj}\,A}{|A|}$$

$$\text{Adj}\,A = \begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix}$$

$$|A| = \frac{1}{3}$$

$$A^{-1} = \frac{1}{3}\begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix}$$

From equation (5)

$$V_p = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix}\begin{bmatrix} 0.5 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 2 \end{bmatrix}\begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix} I_p = \begin{bmatrix} 1 & 0.5 & 0.5 \\ 0.5 & 1 & 0.5 \\ 0.5 & 0.5 & 1 \end{bmatrix} I_p \quad \ldots(6)$$

Comparing of equation (5) and (6)

$$Z = \begin{bmatrix} 1 & 0.5 & 0.5 \\ 0.5 & 1 & 0.5 \\ 0.5 & 0.5 & 1 \end{bmatrix}$$

SOL 1.5.56 Option (A) is correct.

Given that the first two power system are not connected and separately loaded. Now these are connected by short transmission line.

as $P_1 = P_2 = Q_1 = Q_2 = 0$

So here no energy transfer. The bus bar voltage and phase angle of each system should be same than angle difference is

$$\theta = 30^\circ - 20^\circ$$
$$= 10^\circ$$

SOL 1.5.57 Option (B) is correct.

Given that,

230 V, 50 Hz, 3-ϕ, 4-wire system

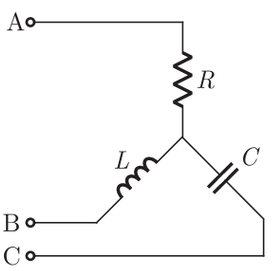
P = Load = 4 kw at unity Power factor

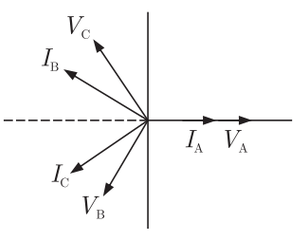
$I_N = 0$ through the use of pure inductor and capacitor

Than $L = ?, C = ?$

$\because$ $I_N = 0 = I_A + I_B + I_C \quad \ldots(1)$

Network and its Phasor is being as





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Here the inductor is in phase B and capacitor is in Phase C.

We know $P = VI$

So $I_a = \frac{P}{V} = \frac{4 \times 10^3}{230} = 17.39$ Amp.

From equation (1)

$$\overline{I_A} = -(\overline{I_B} + \overline{I_C}) \qquad \because I_b \simeq I_c$$

$$\therefore \quad I_A = -\left(I_B \times \frac{\sqrt{3}}{2} + I_C \times \frac{\sqrt{3}}{2}\right)$$

$$\therefore \quad I_A = \sqrt{3}\, I_B = \sqrt{3}\, I_C$$

$$I_B \simeq I_C = \frac{17.39}{\sqrt{3}} \simeq 10 \text{ Amp}$$

Now $X_C = \frac{V}{I_C} = \frac{230}{10} \simeq 23\,\Omega$

and $X_C = \frac{1}{2\pi f C}$

$$\Rightarrow \quad C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 50 \times 23} = 139.02\,\mu\text{F}$$

$$X_L = \frac{V}{I_L} = \frac{230}{10} \simeq 23\,\Omega = 2\pi f L$$

$$\Rightarrow \quad L = \frac{X_L}{2\pi f} = \frac{23}{2\pi \times 100} = 72.95 \text{ mH}$$

So $L = 72.95$ mH in phase B

$C = 139.02$ μF in phase C

SOL 1.5.58 Option (A) is correct.

Maximum continuous power limit of its prime mover with speed governor of 5% droop.

Generator feeded to three loads of 4 MW each at 50 Hz.

Now one load Permanently tripped

$\therefore \quad f = 48$ Hz

If additional load of 3.5 MW is connected than $f = ?$

$\because$ Change in Frequency w.r.t to power is given as

$$\Delta f = \frac{\text{drop out frequency}}{\text{rated power}} \times \text{Change in power}$$

$$= \frac{5}{15} \times 3.5 = 1.16\% = 1.16 \times \frac{50}{100} = 0.58\,\text{Hz}$$

System frequency is $= 50 - 0.58 = 49.42\,\text{Hz}$

SOL 1.5.59 Option (B) is correct.

With the help of physical length of line, we can recognize line as short, medium and long line.

SOL 1.5.60 Option (A) is correct.

For capacitor bank switching vacuum circuit breaker is best suited in view of cost and effectiveness.

SOL 1.5.61 Option (B) is correct.

Ratio of operating coil current to restraining coil current is known as bias in biased differential relay.

SOL 1.5.62 Option (B) is correct.

HVDC links consist of rectifier, inverter, transmission lines etc, where rectifier

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consumes reactive power from connected AC system and the inverter supplies power to connected AC system.

SOL 1.5.63 Option (C) is correct.

Given $ABCD$ constant of 220 kV line

$A = D = 0.94\angle 10^\circ$, $B = 130\angle 730^\circ$, $C = 0.001\angle 900^\circ$, $V_S = 240$ kV

% voltage regulation is being given as

$$\%\text{V.R.} = \frac{(V_R)_{\text{No Load}} - (V_R)_{\text{Full load}}}{V_R(\text{Full load})} \times 100$$

At no load $I_R = 0$

$$(V_R)_{NL} = V_S/A,\ (V_R)_{\text{Full load}} = 220 \text{ kV}$$

$$\%\text{V.R.} = \frac{\frac{240}{0.94} - 220}{220} \times 100$$

$$\%\text{V.R.} = 16$$

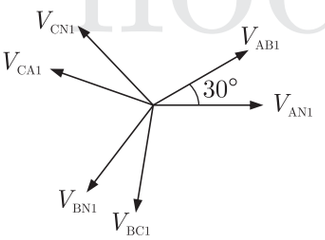
SOL 1.5.64 Option ( ) is correct.

SOL 1.5.65 Option (B) is correct.

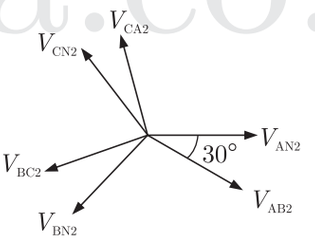
Given that,

$V_{ab1} = X\angle\theta_1$, $V_{ab2} = Y\angle\theta_2$, Phase to neutral sequence volt= ?

First we draw phasor of positive sequence and negative sequence.



Positive sequence



Negative sequence

From figure we conclude that positive sequence line voltage leads phase voltage by 30°

$$V_{AN1} = X\angle\theta_1 - 30^\circ$$

$$V_{AN2} = 4\angle\theta_2 + 30^\circ$$

SOL 1.5.66 Option (A) is correct.

For system base value 10 MVA, 69 kV, Load in pu(Z_{new}) = ?

$$Z_{\text{new}} = Z_{\text{old}} \times \frac{(\text{MVA})_{\text{old}}}{(\text{MVA})_{\text{new}}} \times \left(\frac{\text{kV}_{\text{new}}}{\text{kV}_{\text{old}}}\right)^2$$

$$Z_{\text{new}} = 0.72 \times \frac{20}{10} \times \left(\frac{69}{13.8}\right)^2 = 36 \text{ pu}$$

SOL 1.5.67 Option (A) is correct.

Unreliable convergence is the main disadvantage of gauss seidel load flow method.

SOL 1.5.68 Option (C) is correct.

Generator feeds power to infinite bus through double circuit line 3-ϕ fault at middle of line.

Infinite bus voltage(V) = 1 pu

Transient internal voltage of generator(E)= 1.1 pu

Equivalent transfer admittance during fault = 0.8 pu = $1/X$

delivering power(P_S) = 1.0 pu

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Perior to fault rotor Power angle $\delta = 30^\circ$, $f = 50\,\text{Hz}$

Initial accelerating power(P_a)= ?

$$P_a = P_S - P_{m2}\sin\delta$$
$$= 1 - \frac{EV}{X}\sin 30^\circ = 1 - \frac{1.1 \times 1}{1/0.8} \times \frac{1}{2} = 0.56 \text{ pu}$$

SOL 1.5.69 Option (B) is correct.

If initial acceleration power $= X$ pu

Initial acceleration = ?

Inertia constant = ?

$$\alpha = \frac{P_a}{M} = \frac{X(\text{pu}) \times \text{S}}{\text{SH}/180\text{F}} = \frac{180 \times 50 \times X \times S}{S \times S}$$

$$\alpha = 1800X \text{ deg}/\text{sec}^2$$

$$\text{Inertia const.} = \frac{1}{18} = 0.056$$

SOL 1.5.70 Option (D) is correct.

The post fault voltage at bus 1 and 3 are.

Pre fault voltage.

$$V_{\text{Bus}} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 1\angle 0^\circ \\ 1\angle 0^\circ \\ 1\angle 0^\circ \end{bmatrix}$$

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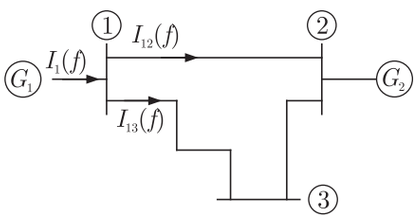
At bus 2 solid fault occurs $Z(f) = 0$, $r = 2$

$$\text{Fault current } I_f = \frac{V_r^\circ}{Z_{rr} + Z_f} = \frac{V_2^\circ}{Z_{22} + Z_f}$$

$$Z_f = \frac{1\angle 0^\circ}{j0.24} = -4j$$



$V_i(f) = V_i^\circ(0) - Z_{ir}I(f)$, V_i° = Prefault voltage

$V_1(f) = V_i^\circ - Z_{12}I_f = 1\angle 0^\circ - j0.08(-j4) = 1 - 0.32$

$V_1(f) = 0.68$ pu

$V_3(f) = V_3^\circ - Z_{32}I_f = 1\angle 0^\circ - j0.16(-j4) = 1 - 0.64$

$V_3(f) = 0.36$ pu

SOL 1.5.71 Option ( ) is correct.

SOL 1.5.72 Option (D) is correct.

Rating of Δ-connected capacitor bank for unity p.f.

real power $P_L = S\cos\phi = 12\sqrt{3} \times 0.8 = 16.627$ kW

reactive power $Q_L = S\sin\phi = 12\sqrt{3} \times 0.6 = 12.47$ kW

For setting of unity p.f. we have to set capacitor bank equal to reactive power = 12.47 kW

SOL 1.5.73 Option (D) is correct.

Given that pu parameters of 500 MVA machine are as following

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$$M = 20 \text{ pu}, \; X = 2 \text{ pu}$$

Now value of M and X at 100 MVA base are

for inertia (M)

$$(\text{pu})_{\text{new}} = (\text{pu})_{\text{old}} \times \frac{\text{old MVA}}{\text{new MVA}}$$

$$(M_{\text{pu}})_{\text{new}} = (M_{\text{Pu}})_{\text{old}} \times \frac{500}{100} = 20 \times \frac{5}{1} = 100 \text{ pu}$$

and for reactance (X)

$$(\text{pu})_{\text{new}} = (\text{pu})_{\text{old}} \times \frac{\text{new MVA}}{\text{old MVA}}$$

$$(X_{\text{pu}})_{\text{new}} = (X_{\text{pu}})_{\text{old}} \times \frac{100}{500}$$

$$(X_{\text{Pu}})_{\text{new}} = 2 \times \frac{1}{5} = 0.4 \text{ pu}$$

SOL 1.5.74 Option (D) is correct.

800 kV has Power transfer capacity $= P$

At 400 kV Power transfer capacity $= ?$

We know Power transfer capacity

$$P = \frac{EV}{X}\sin\delta$$

$$P \propto V^2$$

So if V is half than Power transfer capacity is $\frac{1}{4}$ of previous value.

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SOL 1.5.75 Option (B) is correct.

In EHV lines the insulation strength of line is governed by the switching over voltages.

SOL 1.5.76 Option (A) is correct.

For bulk power transmission over very long distance HVDC transmission preferably used.

SOL 1.5.77 Option (D) is correct.

Parameters of transposed overhead transmission line

$X_S = 0.4\,\Omega/\text{km}, \; X_m = 0.1\,\Omega/\text{km}$

$+$ve sequence reactance $X_1 = ?$

Zero sequence reactance $X_0 = ?$

We know for transposed overhead transmission line.

$+$ve sequence component $X_1 = X_S - X_m = 0.4 - 0.1 = 0.3\,\Omega/\text{km}$

Zero sequence component $X_0 = X_S + 2X_m = 0.4 + 2(0.1) = 0.6\,\Omega/\text{km}$

SOL 1.5.78 Option (C) is correct.

Industrial substation of 4 MW load $= P_L$

$Q_C = 2\,\text{MVAR}$ for load p.f. $= 0.97$ lagging

If capacitor goes out of service than load p.f. $= ?$

$$\cos\phi = 0.97$$

$$\tan\phi = \tan(\cos^{-1}0.97) = 0.25$$

$$\frac{Q_L - Q_C}{P_L} = 0.25$$

$$\frac{Q_L - 2}{4} = 0.25 \Rightarrow Q_L = 3\,\text{MVAR}$$

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$$\phi = \tan^{-1}\left(\frac{Q_L}{P_L}\right) = \tan^{-1}\left(\frac{3}{4}\right) = 36^\circ$$

$$\cos\phi = \cos 36^\circ = 0.8 \text{ lagging}$$

SOL 1.5.79 Option (D) is correct.

$$Y_{22} = ?$$

$$I_1 = V_1 Y_{11} + (V_1 - V_2) Y_{12}$$

$$= 0.05V_1 - j10(V_1 - V_2) = -j9.95V_1 + j10V_2$$

$$I_2 = (V_2 - V_1) Y_{21} + (V_2 - V_3) Y_{23}$$

$$= j10V_1 - j9.9V_2 - j0.1V_3$$

$$Y_{22} = Y_{11} + Y_{23} + Y_2 = -j9.95 - j9.9 - 0.1j = -j19.95$$

SOL 1.5.80 Option (C) is correct.

$$F_1 = a + bP_1 + cP_1^2 \text{ Rs/hour}$$

$$F_2 = a + bP_2 + 2cP_2^2 \text{ Rs/hour}$$

For most economical operation

$$P_1 + P_2 = 300 \text{ MW then } P_1, P_2 = ?$$

We know for most economical operation

$$\frac{\partial F_1}{\partial P_1} = \frac{\partial F_2}{\partial P_2}$$

$$2cP_1 + b = 4cP_2 + b$$

$$P_1 = 2P_2 \quad \ldots(1)$$

$$P_1 + P_2 = 300 \quad \ldots(2)$$

from eq (1) and (2)

$$P_1 = 200 \text{ MW}, \; P_2 = 100 \text{ MW}$$

SOL 1.5.81 Option (B) is correct.

We know that $ABCD$ parameters $\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_1 \end{bmatrix}$

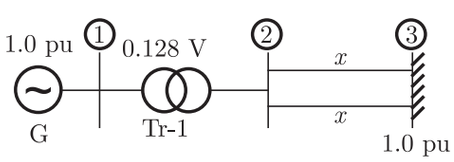
$$B = \frac{V_1}{I_2}\bigg|_{V_2=0}, \; C = \frac{I_1}{V_2}\bigg|_{I_2=0}$$

In figure $$C = \frac{\frac{V_1}{Z_1 + Z_2}}{\frac{V_1}{Z_1 + Z_2} \times Z_2} = \frac{1}{Z_2}$$

or $$Z_2 = \frac{1}{C} = \frac{1}{0.025 \angle 45^\circ} = 40 \angle -45^\circ$$

SOL 1.5.82 Option (D) is correct.

Given



Steady state stability Power Limit = 6.25 pu

If one of double circuit is tripped than

Steady state stability power limit = ?

$$P_{m1} = \frac{EV}{X} = \frac{1 \times 1}{0.12 + \frac{X}{2}} = 6.25$$

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$$\frac{1}{0.12+0.5X} = 6.25$$

$$\Rightarrow \quad X = 0.008 \text{ pu}$$

If one of double circuit tripped than

$$P_{m2} = \frac{EV}{X} = \frac{1\times 1}{0.12+X} = \frac{1}{0.12+0.08}$$

$$P_{m2} = \frac{1}{0.2} = 5 \text{ pu}$$

SOL 1.5.83 Option (D) is correct.

Given data

Substation Level = 220 kV

3-ϕ fault level = 4000 MVA

LG fault level = 5000 MVA

Positive sequence reactance:

$$\text{Fault current } I_f = \frac{4000}{\sqrt{3}\times 220}$$

$$X_1 = V_{ph}/I_f$$

$$= \frac{\frac{220}{\sqrt{3}}}{\frac{4000}{\sqrt{3}\times 220}} = \frac{220\times 220}{4000} = 12.1\,\Omega$$

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SOL 1.5.84 Option (B) is correct.

Zero sequence Reactance $X_0 = ?$

$$I_f = \frac{5000}{\sqrt{3}\times 220}$$

$$I_{a1} = I_{a2} = I_{a0} = \frac{I_f}{3} = \frac{5000}{3\sqrt{3}\times 220}$$

$$X_1 + X_2 + X_0 = \frac{V_{ph}}{I_{a1}} = \frac{\frac{220}{\sqrt{3}}}{\frac{5000}{220\times 3\sqrt{3}}}$$

$$X_1 + X_2 + X_0 = \frac{220\times 220}{3\times 5000} = 29.04\,\Omega$$

$$X_1 = X_2 = 12.1\,\Omega$$

$$X_0 = 29.04 - 12.1 - 12.1 = 4.84\,\Omega$$

SOL 1.5.85 Option (B) is correct.

Instantaneous power supplied by 3-ϕ ac supply to a balanced R-L load.

$$P = V_a I_a + V_a I_b + V_c I_c$$

$$= (V_m \sin\omega t) I_m \sin(\omega t - \phi) + V_m \sin(\omega t - 120^\circ) I_m \sin(\omega t - 120^\circ - \phi)$$
$$+ V_m \sin(\omega t - 240^\circ) I_m \sin(\omega t - 240^\circ - \phi)$$

$$= VI[\cos\phi - \cos(2\omega t - \phi) + \cos\phi - \cos(2\omega t - 240 - \phi) + \cos\phi$$
$$- \cos(2\omega t + 240 - \phi)]$$

$$P = 3VI\cos\phi \qquad \ldots(1)$$

equation (1) implies that total instantaneous power is being constant.

SOL 1.5.86 Option (C) is correct.

In 3-ϕ Power system, the rated voltage is being given by RMS value of line to

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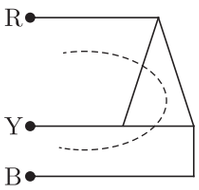
line voltage.

SOL 1.5.87 Option (B) is correct.



In this figure the sequence is being given as RBY

SOL 1.5.88 Option (C) is correct.
In thermal power plants, the pressure in the working fluid cycle is developed by the help to feed water pump.

SOL 1.5.89 Option (A) is correct.
Kaplan turbines are used for harnessing low variable waterheads because of high percentage of reaction and runner adjustable vanes.

SOL 1.5.90 Option (B) is correct.
MHO relay is the type of distance relay which is used to transmission line protection. MHO Relay has the property of being inherently directional.

SOL 1.5.91 Option (C) is correct.
Surge impedance of line is being given by as

$$Z = \sqrt{\frac{L}{C}} = \sqrt{\frac{11 \times 10^{-3}}{11.68 \times 10^{-9}}} = 306.88\,\Omega$$

Ideal power transfer capability

$$P = \frac{V^2}{Z_0} = \frac{(800)^2}{306.88} = 2085 \text{ MW}$$

SOL 1.5.92 Option (D) is correct.
Given that,

$$\text{Power cable voltage} = 110 \text{ kV}$$
$$C = 125 \text{ nF/km}$$
$$\text{Dielectric loss tangent} = \tan\delta = 2 \times 10^{-4}$$
$$\text{Dielectric power loss} = ?$$

dielectric power loss is given by

$$\begin{aligned} P &= 2V^2\,\omega C \tan\delta \\ &= 2(110 \times 10^3)^2 \times 2\pi f \times 125 \times 10^{-9} \times 2 \times 10^{-4} \\ &= 2(121 \times 10^8 \times 2 \times 3.14 \times 50 \times 250 \times 10^{-13}) = 189 \text{ W/km} \end{aligned}$$

SOL 1.5.93 Option (A) is correct.
Given data
Lightening stroke discharge impulse current of $I = 10$ kA

$$\text{Transmission line voltage} = 400 \text{ kV}$$
$$\text{Impedance of line } Z = 250\,\Omega$$
$$\text{Magnitude of transient over-voltage} = ?$$

The impulse current will be equally divided in both directions since there is equal distribution on both sides.
Then magnitude of transient over-voltage is

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$$V = IZ/2 = \frac{10}{2} \times 10^3 \times 250$$
$$= 1250 \times 10^3 \text{ V} = 1250 \text{ kV}$$

SOL 1.5.94 Option (C) is correct.

The A, B, C, D parameters of line

$$A = D = 0.936 \angle 0.98^\circ$$
$$B = 142 \angle 76.4^\circ$$
$$C = (-5.18 + j914)10^{-6}\ \Omega$$

At receiving end $P_R = 50\,\text{MW}$, $V_R = 220$ kV

$$\text{p.f} = 0.9 \text{ lagging}$$
$$V_S = ?$$

Power at receiving end is being given by as follows

$$P_R = \frac{|V_S||V_R|}{|B|}\cos(\beta - \delta) - \frac{|A||V_R|^2}{|B|}\cos(\beta - \alpha)$$
$$= \frac{|V_S| \times 220}{142}\cos(76.4^\circ - \delta) - \frac{0.936(220)^2}{142}\cos 75.6^\circ$$

$$\therefore V_S \cos(76.4 - \delta) = \frac{50 \times 142}{220} + 0.936 \times 220 \times 0.2486 = 32.27 + 51.19$$

$$V_S \cos(76.4 - \delta) = 83.46 \quad \ldots(1)$$

Same as $Q_R = P_R \tan\phi = P_R \tan(\cos^{-1}\phi) = 50\tan(\cos^{-1}0.9)$

$$= 24.21 \text{ MW}$$

$$Q_R = \frac{|V_S||V_R|}{|B|}\sin(\beta - \delta) - \frac{|A||V_R|^2}{|B|}\sin(\beta - \alpha)$$
$$= \frac{|V_S| \times 220}{142}\sin(76.4^\circ - \delta) - \frac{0.936 \times (220)^2}{142}\sin 75.6^\circ$$

$$(24.21)\frac{142}{220} + 0.936 \times 220 \times 0.9685 = |V_S|\sin(76.4^\circ - \delta) \quad \ldots(2)$$

from equation (1) & (2)

$$|V_S|^2 = (215)^2 + (83.46)^2$$
$$|V_S| = \sqrt{53190.5716} = 230.63 \text{ kV}$$

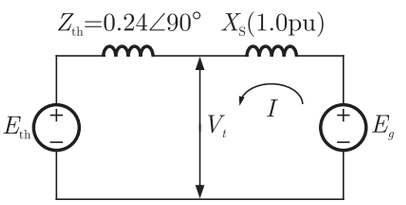
SOL 1.5.95 Option (B) is correct.

A new generator of $E_g = 1.4 \angle 30^\circ$ pu

$X_S = 1.0$ pu, connected to bus of V_t Volt

Existing Power system represented by thevenin's equivalent as

$E_{th} = 0.9 \angle 0^\circ$, $Z_{th} = 0.25 \angle 90^\circ$, $V_t = ?$



From the circuit given

$$I = \frac{E_g - E_{th}}{Z_{th} + X_S} = \frac{1.4 \angle 30^\circ - 0.9 \angle 0^\circ}{j(1.25)} = \frac{1.212 + j7 - 0.9}{j(1.25)}$$
$$= \frac{0.312 + j7}{j(1.25)} = 0.56 - 0.2496j$$

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$$V_t = E_g - IX_S = 1.212 + j7 - (0.56 - 0.2496j)(j1)$$
$$= 1.212 - 0.2496 + j(0.7 - 0.56) = 0.9624 + j0.14$$
$$V_t = 0.972\angle 8.3^\circ$$

SOL 1.5.96 Option (C) is correct.

Given that

3-ϕ Generator rated at 110 MVA, 11 kV

$$X_d'' = 19\%,\ X_d' = 26\%$$
$$X_S = 130\%, \text{ Operating at no load}$$

3-ϕ short circuit fault between breaker and transformer

symmetrical I_{rms} at breaker = ?

We know short circuit current

$$I_{sc} = \frac{1}{X_d''} = \frac{1}{j0.19} = -j5.26 \text{ pu}$$

$$\text{Base current } I_B = \frac{\text{rating MVA of generator}}{\sqrt{3} \times \text{kV of generator}}$$

$$I_B = \frac{110 \times 10^6}{\sqrt{3} \times 11 \times 10^3}$$

$$I_B = 5773.67 \text{ Amp}$$

$$\text{Symmetrical RMS current} = I_B \times I_{sc}$$
$$= 5773.67 \times 5.26 = 30369.50 \text{ Amp}$$
$$\Rightarrow I_{rms} = 30.37 \text{ kA}$$

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SOL 1.5.97 Option (A) is correct.

$$+\text{ve sequence current } I_a = \frac{1}{3}[I_a + \alpha I_b + \alpha^2 I_c]$$
$$= \frac{1}{3}[10\angle 0^\circ + 1\angle 120^\circ \times 10\angle 180^\circ + 0]$$
$$= \frac{1}{3}[10\angle 0^\circ + 10\angle 300^\circ] = \frac{1}{3}[10 + 5 - j8.66]$$
$$= \frac{1}{3}[15 - j8.66] = \frac{17.32\angle -30^\circ}{3}$$
$$= 5.78\angle -30^\circ$$

SOL 1.5.98 Option (D) is correct.

Given data 500 MVA , 50 Hz, $3-\phi$ generator produces power at 22 kV

Generator $\rightarrow Y$ connected with solid neutral

Sequence reactance $X_1 = X_2 = 0.15,\ X_0 = 0.05$ pu

Sub transient line current = ?

$$I_{a1} = \frac{E}{Z_1 + Z_2 + Z_0} = \frac{1}{j0.15 + j0.15 + j0.05} = \frac{1}{0.35j} = -2.857j$$

Now sub transient Line current $I_a = 3I_{a1}$

$$I_a = 3(-2.857j) = -8.57j$$

SOL 1.5.99 Option (B) is correct.

Given: 50 Hz, 4-Pole, 500 MVA, 22 kV generator

p.f. = 0.8 lagging

Fault occurs which reduces output by 40%.

Accelerating torque = ?

$$\text{Power} = 500 \times 0.8 = 400 \text{ MW}$$

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After fault, Power $= 400 \times 0.6 = 240$ MW

$$\because P_a = T_a \times \omega$$

$$T_a = \frac{P_a}{\omega}$$

Where $\omega = 2\pi f_{\text{mechanical}}$

$$f_{\text{mechanical}} = f_{\text{electrical}} \times \frac{2}{P} = f_{\text{electrical}} \times \frac{2}{4}$$

$$P_a = 400 - 240 = 160\,\text{MW}$$

$$T_a = \frac{160}{2 \times \pi \times 50/2}$$

$$T_a = 1.018 \text{ MN}$$

SOL 1.5.100 Option (D) is correct.

Turbine rate speed $N = 250$ rpm

To produce power at

$$f = 50 \text{ Hz.}$$

No. of Poles $P = ?$

$$\because N = \frac{120}{P} f$$

$$P = \frac{120}{N} f = \frac{120 \times 50}{250} = 24$$

$$P = 24 \text{ Poles}$$

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SOL 1.5.101 Option (C) is correct.

In case of bundled conductors, We know that self GMD of conductor is increased and in a conductor critical disruptive voltage of line depends upon GMD of conductor. Since GMD of conductor is increased this causes critical disruptive voltage is being reduced and if critical disruptive voltage is reduced, the corona loss will also be reduced.

SOL 1.5.102 Option (B) is correct.

Given that no. of buses $n = 300$

Generator bus $= 20$

Reactive power support buses $= 25$

Fixed buses with Shunt Capacitor $= 15$

Slack buses $(n_s) = 20 + 25 - 15 = 30$

$\because$ Size of Jacobian Matrix is given as

$$= 2(n - n_s) \times 2(n - n_s)$$

$$= 2(300 - 30) \times 2(300 - 30)$$

$$= 540 \times 540$$

SOL 1.5.103 Option (B) is correct.

Auxiliary component in HVDC transmission system are DC line inductor and reactive power sources.

SOL 1.5.104 Option (C) is correct.

$\because$ Exchanged electrical power is being given as follows

$$P = \frac{EV}{X_d}[\sin(\delta_1 - \delta_2)] \quad \ldots(1)$$

Given that $P \rightarrow$ Power supply by generator $= 0.5$ pu

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$E \rightarrow$ Voltage for rotar generator $= 2.0$ pu

$V \rightarrow$ Voltage of motor rotor $= 1.3$ pu

$X_d = X_{eq}$ = Reactance of generator + Reactance of motor + Recatance of connecting line

$X_d = 1.1 + 1.2 + 0.5 = 2.8$

$\delta_1 - \delta_2$ = Rotor angle difference = ?

from eq(1), $0.5 = \dfrac{2 \times 1.3}{2.8} \sin(\delta_1 - \delta_2)$

$$\Rightarrow \delta_1 - \delta_2 = \sin^{-1}\left(\frac{2.8 \times 0.5}{2.6}\right)$$

$$\Rightarrow \delta_1 - \delta_2 = 32.58$$

SOL 1.5.105 Option (B) is correct.

Time period between energization of trip circuit and the arc extinction on an opening operation is known as the interrupting time of Circuit breaker.

SOL 1.5.106 Option (B) is correct.

Given that $ABCD$ parameters of line as

$$A = D = 0.9 + 0\text{c},\ B = 200\angle 90^\circ\ \Omega,\ C = 0.95\ \#\ 10^{-3} + 90\text{℅ S}.$$

at no-load condition,

Receiving end voltage (V_R) = sending end voltage (V_S)

ohmic value of reactor = ?

We know

$$V_S = AV_R + BI_R$$

$$V_S = V_R$$

$$V_R = AV_R + BI_R$$

$$V_R(1 - A) = BI_R$$

$$\frac{V_R}{I_R} = \frac{B}{1 - A} = \frac{200\angle 90^\circ}{1 - 0.9\angle 0^\circ}$$

$$\frac{V_R}{I_R} = 2000\angle 90^\circ$$

The ohmic value of reactor $= 2000\,\Omega$

SOL 1.5.107 Option (A) is correct.

Surge impedance of cable

$$Z_1 = \sqrt{\frac{L}{C}}; \qquad L = 0.4 \text{ mH/km},\ C = 0.5\,\mu\text{F/km}$$

$$= \sqrt{\frac{0.4 \times 10^{-3}}{0.5 \times 10^{-6}}} = 28.284$$

surge impedance of overhead transmission line

$$Z_2 = Z_3 = \sqrt{\frac{L}{C}}; \qquad L = 1.5 \text{ mm/km}, C = 0.015\,\mu\text{F/km}$$

$$Z_2 = Z_3 = \sqrt{\frac{1.5 \times 10^{-5}}{0.015 \times 10^{-6}}} = 316.23$$

Now the magnitude of voltage at junction due to surge is being given by as

$$V' = \frac{2 \times V \times Z_2}{Z_2 + Z_1} \qquad V = 20 \text{ kV}$$

$$= \frac{2 \times 20 \times 10^3 \times 316.23}{316 + 28.284}$$

$$= 36.72 \text{ kV}$$

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SOL 1.5.108 Option (D) is correct.

Let that current in line is I amp than

from figure current in line section PR is $(I-10)$ amp

current in line section RS is $(I-10-20)=(I-30)$ amp

current in SQ Section is $(I-30-30)=(I-60)$ amp

Given that V_P and V_Q are such that

$$V_P - V_Q = 3\text{ V}$$

by applying KVL through whole line

$$V_P - V_Q = (I-10)0.1 + (I-30)0.15 + (I-60)\times 0.2$$

$$\Rightarrow 3 = 0.45I - 17.5$$

$$I = \frac{20.5}{0.45} = 45.55 \text{ amp}$$

Now the line drop is being given as

$$= (I-10)0.1 + (I-30)0.15 + (I-60)0.2$$

$$= (33.55)0.1 + (15.55)0.15 + (14.45)0.2$$

$$= 8.58\text{ V}$$

The value of V_P for minimum voltage of 220 V at any feeder is

$$= 220 + \text{Line voltage} = 220 + 8.58$$

$$= 228.58\text{ V}$$

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SOL 1.5.109 Option (D) is correct.

$$\text{Given Load Power} = 100\text{ MW}$$

$$V_S = V_R = 11\text{ kV}$$

$$\text{Impedance of line } Z_L = \frac{\text{p.u.}\times(\text{kV})^2}{\text{MV}} = \frac{j0.2\times(11)^2}{100} = j0.242\,\Omega$$

We know $$P_L = \frac{|V_S||V_R|\sin\delta}{X}$$

$$100\times 10^6 = \frac{11\times 10^3\times 11\times 10^3}{0.242}\sin\delta$$

$$\frac{100\times 0.242}{121} = \sin\delta$$

$$\delta = \sin^{-1}(0.2) = 11.537^\circ$$

Reactive Power is being given by

$$Q_L = \frac{|V_S||V_R|}{X}\cos\delta - \frac{|V_R|^2}{X}$$

$$= \frac{11\times 10^3\times 11\times 10^3}{0.242}\cos(11.537^\circ) - \frac{(11\times 10^3)^2}{0.242}$$

$$= \frac{121\times 10^6}{0.242}[\cos(11.537^\circ) - 1] = -10.1\text{ MVAR}$$

SOL 1.5.110 Option (B) is correct.

Given the bus Impedance Matrix of a 4-bus Power System

$$Z_{\text{bus}} = \begin{bmatrix} j0.3435 & j0.2860 & j0.2723 & j0.2277 \\ j0.2860 & j0.3408 & j0.2586 & j0.2414 \\ j0.2723 & j0.2586 & j0.2791 & j0.2209 \\ j0.2277 & j0.2414 & j0.2209 & j0.2791 \end{bmatrix}$$

Now a branch os $j0.2\,\Omega$ is connected between bus 2 and reference

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$$Z_{B_{(\text{New})}} = Z_{B(\text{Old})} - \frac{1}{Z_{ij} + Z_b}\begin{bmatrix} Z_{ij} \\ \vdots \\ Z_{nj} \end{bmatrix}\begin{bmatrix} Z_{ji} & \cdots & Z_{jn} \end{bmatrix}$$

New element $Z_b = j0.2\,\Omega$ is connected in j^{th} and reference bus

$j = 2,\ n = 4$ so

$$\frac{1}{Z_{ij} + Z_b}\begin{bmatrix} Z_{12} \\ Z_{22} \\ Z_{23} \\ Z_{24} \end{bmatrix}\begin{bmatrix} Z_{21} & Z_{22} & Z_{23} & Z_{24} \end{bmatrix}$$

$$= \frac{1}{[j(0.3408) + j0.2]}\begin{bmatrix} j0.2860 \\ j0.3408 \\ j0.2586 \\ j0.2414 \end{bmatrix}\begin{bmatrix} j0.2860 & j0.3408 & j0.2586 & j0.2414 \end{bmatrix} \ldots(1)$$

Given that we are required to change only Z_{22}, Z_{23}

So in equation (1) $\quad Z'_{22} = \dfrac{j^2(0.3408)^2}{j(0.5408)} = j0.2147$

$$Z'_{23} = \frac{j^2(0.3408)(0.2586)}{0.5408} = j0.16296$$

$$Z_{22(\text{New})} = Z_{22(\text{Old})} - Z'_{22} = j0.3408 - j0.2147 = j0.1260$$

$$Z_{23(\text{New})} = Z_{23(\text{Old})} - Z'_{23} = j0.2586 - j0.16296 = j0.0956$$

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SOL 1.5.111 Option (D) is correct.

Total zero sequence impedance, $+ve$ sequence impedance and $-ve$ sequence impedances

$$Z_0 = (Z_0)_{\text{Line}} + (Z_0)_{\text{Generator}} = j0.04 + j0.3 = j0.34 \text{ pu}$$
$$Z_1 = (Z_1)_{\text{Line}} + (Z_1)_{\text{Generator}} = j0.1 + j0.1 = j0.2 \text{ pu}$$
$$Z_2 = (Z_2)_{\text{Line}} + (Z_2)_{\text{Generator}} = j0.1 + j0.1 = j0.2 \text{ pu}$$
$$Z_n = j0.05 \text{ pu}$$

for L-G fault

$$I_{a1} = \frac{E_a}{Z_0 + Z_1 + Z_2 + 3Z_n} = \frac{0.1}{j0.2 + j0.2 + j0.34 + j0.15}$$
$$= -j1.12 \text{ pu}$$
$$I_B = \frac{\text{generator MVA}}{\sqrt{3}\,\text{generator kV}} = \frac{20 \times 10^6}{\sqrt{3} \times 6.6 \times 10^3} = 1750 \text{ Amp}$$

Fault current

$$I_f = (3I_a)I_B = 3(-j1.12)(1750) = -j5897.6 \text{ Amp}$$

Neutral Voltage

$$V_n = I_f Z_n$$

and $\quad Z_n = Z_B \times Z_{\text{pu}}$

$$= \frac{(6.6)^2}{20} \times 0.05 = 0.1089\,\Omega$$

$$V_n = 5897.6 \times 0.1089 = 642.2 \text{ V}$$

SOL 1.5.112 Option (A) is correct.

We know that Optimal Generation

$$IC_1 = IC_2, \text{ and } P_3 = 300 \text{ MW (maximum load)}$$
$$IC_3 = 30 \qquad \text{(Independent of load)}$$

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$$20 + 0.3P_1 = 30 + 0.4\,P_2$$

$$0.3P_1 - 0.4P_2 = 10 \quad \ldots(1)$$

$$P_1 + P_2 + P_3 = 700$$

$$P_1 + P_2 + 300 = 700$$

$$P_1 + P_2 = 400 \quad \ldots(2)$$

From equation (1) and (2)

$$P_1 = 242.8 \text{ MW}$$

$$P_2 = 157.14 \text{ MW}$$

SOL 1.5.113 Option (A) is correct.

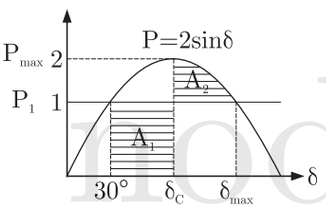
For transmission line protection-distance relay

For alternator protection-under frequency relay

For bus bar protection-differential relay

For transformer protection-Buchholz relay

SOL 1.5.114 Option (C) is correct.



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We know by equal area criteria

$$P_S(\delta_m - \delta_0) = \int_{\delta_c}^{\delta_m} P_{\max} \sin\delta d\delta$$

$$P_{\max}\sin\delta_0(\delta_m - \delta_0) = P_{\max}[\cos\delta_0 - \cos\delta_m] \quad \ldots(1)$$

$$P_{\max} = 2$$

$$P_0 = P_{\max}\sin\delta_0 = 1$$

$$\delta_0 = 30^\circ$$

$$\delta_{\max} = 110^\circ \text{ (given)}$$

Now from equation (1)

$$2\sin 30^\circ (110 - 30)\frac{\pi}{180} = 2[\cos\delta_c - \cos 110^\circ]$$

$$0.5 \times \frac{80\pi}{180} = \cos\delta_c + 0.342$$

$$\cos\delta_c = 0.698 - 0.342$$

$$\delta_c = 69.138^\circ$$

SOL 1.5.115 Option (D) is correct.

$\because$ Both sides are granted

So, $$I_a = \frac{E_a}{Z_a} = \frac{10\angle 0^\circ}{2j} = 5\angle -90^\circ$$

$$I_b = \frac{E_b}{Z_b} = \frac{10\angle -90^\circ}{3j} = 3.33\angle -180^\circ$$

$$I_c = \frac{E_c}{Z_c} = \frac{10\angle 120^\circ}{4j} = 2.5\angle 30^\circ$$

We know $$I_{a_1} = \frac{1}{3}[I_a + \alpha I_b + \alpha^2 I_c]$$

where $\alpha = 1\angle 120^\circ \Rightarrow \alpha^2 = 1\angle 240^\circ$

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$$I_{a1} = \frac{1}{3}[5\angle -90^\circ + 3.33\angle(-180^\circ + 120^\circ) + 2.5\angle(240^\circ + 30^\circ)]$$

$$I_{a1} = \frac{1}{3}[5\angle -90^\circ + 3.33\angle -60^\circ + 2.5\angle 270^\circ]$$

$$= \frac{1}{3}[-5j + 1.665 - j2.883 - 2.5j]$$

$$= \frac{1}{3}[1.665 - j10.383] = 3.5\angle -80.89^\circ$$

SOL 1.5.116 Option (B) is correct.

Given data

A balanced delta connected load $= 8 + 6j = 2$

$V_2 = 400$ volt

Improved Power Factor $\cos\phi_2 = 0.9$

$$\phi_1 = \tan^{-1}(6/8) = 36.85^\circ$$

$$\phi_2 = \cos^{-1}(0.9) = 25.84^\circ$$

$$I = \frac{V}{Z} = \frac{400}{8+6j} = \frac{400}{10\angle 36.86^\circ} = 40\angle -36.86^\circ$$

$$= 32 - j24$$

Since Power factor is Improved by connecting a Y-connected capacitor bank like as

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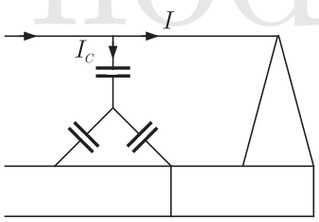
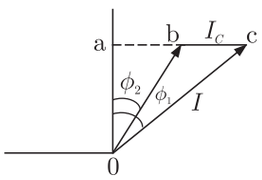


Phasor diagram is being given by as follows



In figure oa $= I'\cos\phi_2 = I\cos\phi_1$

$$I'\cos 25.84^\circ = 32$$

$$I' \times 0.9 = 32$$

$$I' = 35.55$$

ac $= 24$ Amp. $(\text{ac} = I\sin\phi_1)$

ab $= I'\sin\phi_2 = 35.55\sin 25.84^\circ$

ab $= 15.49$ Amp

$I_c = \text{bc} = \text{ac} - \text{ab} = 24 - 15.49 = 8.51$ Amp

$$\text{KVAR of Capacitor bank} = \frac{3 \times V \times I_C}{1000} = \frac{3 \times 400 \times 8.51}{1000}$$

$$= 10.2 \text{ KVAR}$$

SOL 1.5.117 Option (B) is correct.

Given power system with these identical generators

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G1 has Speed governor
G2 and G3 has dr0op of 5%
When load increased, in steady state generation of G1 is only increased while generation of G2 and G3 are unchanged.

SOL 1.5.118 Option (A) is correct.
R_1, R_2-Distance Relay
Zone-1 and Zone-2 setting for both the relays
Correct setting for Zone-2 of relay R_1 and R_2 are given as
$TZ2_{R_1} = 0.6\text{sec}$, $TZ_{R_2} = 0.3$ sec
$\because$ Fault at Zone-2, therefore firstly operated relay is R_2, so time setting of R_2 is 0.3 sec and R_1 is working as back up relay for zone-2, so time setting for R_1 is 0.6 sec.

SOL 1.5.119 Option (B) is correct.
The reactive power absorbed by the rectifier is maximum when the firing angle $\alpha = 30^\circ$.

SOL 1.5.120 Option (D) is correct.
Given a power system consisting of two areas as shown connected by single tie-line

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For load flow study when entering the network data, the tie line data inadvertently left out. If load flow programme is run with this incomplete data than load flow will not converge if only one slack bus is specified.

SOL 1.5.121 Option (D) is correct.
Given that $X_S = 0.2$ pu

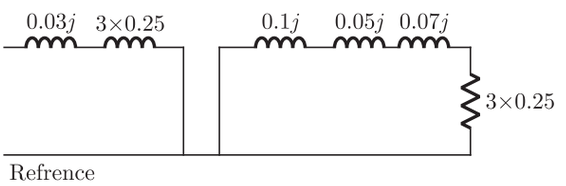
Mid point voltage of transmission line = 0.98 pu

$$V_S = V_R = 1$$

Steady state power transfer limit

$$P = \frac{V_S V_R}{X_S}\sin\delta = \frac{1.1}{0.2}\sin 90^\circ = 5 \text{ pu}$$

SOL 1.5.122 Option (B) is correct.
We have to find out the thevenin's equivalent zero sequence impedance Z_0 at point B.The zero sequence network of system can be drawn as follows



equivalent zero sequence impedance is being given as follows

$$Z_0 = 0.1j + 0.05j + 0.07j + (3 \times 0.25)$$

$$Z_0 = 0.75 + j0.22$$

SOL 1.5.123 *Given data :

$$Z_C = 400\,\Omega \text{ (Characteristics Impedance)}$$

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$$\begin{aligned}
\beta &= 1.2 \times 10^{-3} \text{ rad/km (Propagation constant)}\\
l &= 100 \text{ km (length of line)}\\
P_{\max} &= ? \text{ If } V_S = 230 \text{ kV}\\
V_S &= V_R \cos(\beta l) + jZ_C \sin(\beta l) I_R\\
V_S &= AV_R + BI_R\\
A &= \cos\beta l\\
&= \cos(1.2 \times 10^{-3} \times 100) = 0.9928\angle 0^\circ\\
B &= jZ_C \sin(\beta l)\\
&= j400 \sin(1.2 \times 10^{-3} \times 100) = j47.88\\
&= 47.88\angle 90^\circ\\
V_S &= 230 \text{ kV}, l = 100 \text{ km}
\end{aligned}$$

Since it is a short line, so $V_S \simeq V_R = 230$ kV

again we know for transmission line the equation

$$(P_r - P_{r0})^2 + (Q_r - Q_{r0}) = P_r^2 \qquad ...(1)$$

Where

$$\begin{aligned}
P_{r0} &= -\frac{AV_R^2}{B}\cos(\beta - \alpha)\,\text{MW}\\
Q_{r0} &= -\frac{AV_R^2}{B}\sin(\beta - \alpha)\,\text{MW}\\
P_r &= \frac{V_S V_R}{B}\,\text{MVA}
\end{aligned}$$

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and maximum power transferred is being given by as

$$\begin{aligned}
P_{rm} &= |P_r| - |P_{r0}|\\
P_r &= \frac{V_S V_R}{B} = \frac{230 \times 230}{47.88}\\
P_r &= 1104.84\,\text{MVA}\\
P_{r0} &= -\frac{AV_R^2}{B}\cos(\beta - \alpha)\,\text{MW}\\
&= -\frac{0.9928 \times (230)^2}{47.88} \times \cos(90^\circ - 0)\\
P_{r0} &= 0\,\text{MW}
\end{aligned}$$

So maximum Power transferred

$$P_{rm} = |P_r| - |P_{r0}| = 1104.84\,\text{MW}$$

SOL 1.5.124 *Given: two transposed 3-ϕ line run parallel to each other.

The equation for voltage drop in both side are given as

$$\begin{bmatrix}\Delta V_{a1}\\ \Delta V_{b1}\\ \Delta V_{c1}\\ \Delta V_{a2}\\ \Delta V_{b2}\\ \Delta V_{c2}\end{bmatrix} = j\begin{bmatrix}0.15 & 0.05 & 0.05 & 0.04 & 0.04 & 0.04\\ 0.05 & 0.15 & 0.05 & 0.04 & 0.04 & 0.04\\ 0.05 & 0.05 & 0.15 & 0.04 & 0.04 & 0.04\\ 0.04 & 0.04 & 0.04 & 0.15 & 0.05 & 0.05\\ 0.04 & 0.04 & 0.04 & 0.05 & 0.15 & 0.05\\ 0.04 & 0.04 & 0.04 & 0.05 & 0.05 & 0.15\end{bmatrix}\begin{bmatrix}I_{a1}\\ I_{b1}\\ I_{c1}\\ I_{a2}\\ I_{b2}\\ I_{c2}\end{bmatrix}$$

We have to compute self and mutual zero sequence impedance of the system i.e. $Z_{011}, Z_{012}, Z_{021}, Z_{022}$ in the following equation.

$$\begin{aligned}
\Delta V_{01} &= Z_{011}I_{01} + Z_{021}I_{02}\\
\Delta V_{02} &= Z_{021}I_{01} + Z_{022}I_{02}
\end{aligned}$$

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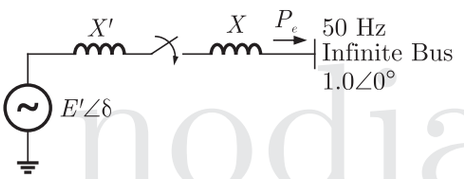
We know that +ve, −ve and zero sequence Impedance can be calculated as respectively.

$$Z_1 = j(X_S - X_m)$$
$$Z_2 = j(X_S - X_m)$$
$$Z_0 = j(X_S + 2X_m)$$

So zero sequence Impedance calculated as

$$Z_{011} = j(X_S + 2X_m) \qquad X_S = 0.15,\ X_m = 0.05$$
$$Z_{011} = j[0.15 \times 2(0.05)] = 0.25j$$
$$Z_{012} = Z_{021} = j(X_S + 2X_m) \qquad X_S = 0.15,\ X_m = 0.04$$
$$Z_{012} = Z_{021} = j[0.15 + 2(0.04)] = 0.23j$$
$$Z_{022} = j(X_S + 2X_m) \qquad X_S = 0.15,\ X_m = 0.05$$
$$= j[0.15 + 2(0.01)]$$
$$= 0.25j$$

SOL 1.5.125 *Given



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$$X = 0.2 \text{ pu}$$

For generator $X' = 0.1$ pu, $E' = 1.0$ pu, $H = 5$ MJ/MVA

Mechanical Power $P_m = 0.0$ pu, $\omega_B = 2\pi \times 50$ rad/sec

Initially generator running on open circuit, at switch closure $\delta = 0$

$$\omega_B = \frac{d\delta}{dt} = \omega_{\text{init}}$$

maximum $\omega_{\text{init}} = ?$, so that generator pulls into synchronism

We know that swing equation

$$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = (P_m - P_e) \text{ pu} \qquad \text{.....(1)}$$

$$P_e = \frac{|E||V|}{X}\sin\delta = \frac{1.1}{0.3}\sin\delta = 3.33\sin\delta$$

From equation (1)

$$\frac{5}{3.14 \times 50}\frac{d^2\delta}{dt^2} = 0 - 3.33\sin\delta$$

$$\frac{d^2\delta}{dt^2} = -104.72\sin\delta$$

integrating on both side.

$$\frac{d\delta}{dt} = 104.72\cos\delta + \delta_0$$

$$\delta_0 = 0 \text{ (given)}$$

$$\omega = \frac{d\delta}{dt}$$

$$\text{For } (\omega_{\text{init}})_{\max} = \left(\frac{d\delta}{dt}\right)_{\max}$$

$\left(\frac{d\delta}{dt}\right)_{\max}$ when $\cos\delta = 1$

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$$(\omega_{\text{init}})_{\max} = \left(\frac{d\delta}{dt}\right)_{\max} = 104.72 \text{ rad/sec}$$

SOL 1.5.126 Option (C) is correct.

A lossless radial transmission line with surge impedance loading has flat voltage profile and unity power factor at all points along it.

SOL 1.5.127 Option (B) is correct.

Given that 3-ϕ transformer, 20 MVA, 220 kV(Y) - 33 kV(Δ)

$$X_l = \text{leakage Reactance} = 12\%$$

$$X = \text{reffered to LV in each phase} = ?$$

$$= 3 \times \frac{(\text{LV side voltage})^2}{\text{MVA Rating}} \times \text{Reactance of Leakage}$$

$$= 3 \times \frac{(33\,\text{kV})^2}{20\,\text{MVA}} \times 0.12 = 19.6\,\Omega$$

SOL 1.5.128 Option (D) is correct.

Given 75 MVA, 10 kV synchronous generator

$$X_d = 0.4 \text{ pu}$$

We have to find out $(X_d)_{\text{new}}$ at 100 MVA, 11 kV

$$(X_d)_{\text{new}} = (X_d)_{\text{old}} \times \left[\frac{(\text{kV})_{\text{old}}}{(\text{kV})_{\text{new}}}\right]^2 \times \left[\frac{(\text{MVA})_{\text{new}}}{(\text{MVA})_{\text{old}}}\right]$$

$$(X_d)_{\text{new}} = 0.4 \times \left(\frac{10}{11}\right)^2 \times \frac{100}{75} = 0.44 \text{ pu}$$

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SOL 1.5.129 Option (A) is correct.

Given Y-alternator: 440 V, 50 Hz

Per phase $X_s = 10\,\Omega$, Capacitive Load current $I = 20$ A

For zero voltage regulation load p.f = ?

Let Load $Z = R + jX$

Zero voltage regulation is given so

$$\overline{E}_{\text{Ph}} - IX_s - I(R + jX) = 0$$

$$\frac{440}{\sqrt{3}} - 20(j10) - 20(R + jX) = 0 \qquad \ldots(1)$$

separating real and imaginary part of equation (1)

$$20R = \frac{440}{\sqrt{3}}$$

$$R = \frac{22}{\sqrt{3}}$$

and

$$20(X + 10) = \frac{440}{\sqrt{3}}$$

$$X = \frac{22}{\sqrt{3}} - 10 = \frac{4.68}{\sqrt{3}}$$

$$\theta = \tan^{-1}\frac{X}{R} = \tan^{-1}\left(\frac{4.68/\sqrt{3}}{22/\sqrt{3}}\right) = \tan^{-1}\left(\frac{4.68}{22}\right)$$

and power factor

$$\cos\theta = \cos\left(\tan^{-1}\frac{4.68}{22}\right)$$

$$\cos\theta = 0.82$$

SOL 1.5.130 Option (B) is correct.

Given 240 V, 1-ϕ AC source, Load Impedance $Z = 10\angle 60^\circ\,\Omega$

Capacitor is in parallel with load and supplies 1250 VAR

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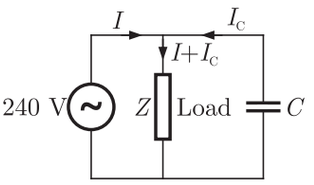
The real power P by source = ?



from figure current through load $I_L = I + I_C$

$$I = \frac{V}{Z} = \frac{240}{10\angle 60^\circ} = 24\angle -60^\circ$$

$$I_C = \frac{\text{VAR}}{V} = \frac{1250}{240} = 5.20j$$

$$I_L = 24\angle -60^\circ + 5.20j = 12 - 15.60j$$

$\because$ apparent power $S = VI = P + jQ = 240(12 + 15.60j)$

$$= 2880 + 3744j = P + jQ$$

Where P = Real Power, Q = Reactive Power

$$P = 2880 \text{ W}$$

SOL 1.5.131 Option ( ) is correct.

SOL 1.5.132 Option (C) is correct.

We have to find out maximum voltage location on line by applying KVL in the circuit

$$V_S - V_R = 0.05j \text{ , where } V_S = 1$$

$$V_R = 1 - 0.05j$$

voltage at $P_1 = V_S = 1 \text{ pu.}$ ..(1)

voltage at $P_2 = 1 - 0.1j$ (by applying KVL) ...(2)

voltage at $P_3 = 1 - 0.1j + j0.15$ (by applying KVL)

$$= 1 + 0.05j \quad ...(3)$$

From equation (1), (2) and (3) it is cleared that voltage at P_3 is maximum.

SOL 1.5.133 Option (B) is correct.

Given: two generators $P_1 = 50(50 - f)$

$$P_2 = 100(51 - f)$$

total load = 400 MW than f = ?

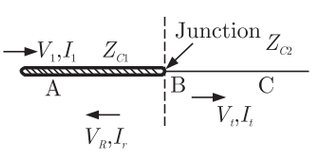
$$P_1 + P_2 = 400$$

$$50(50 - f) + 100(51 - f) = 400$$

$$50 + 102 - 8 = 3f$$

$$f = 48 \text{ Hz}$$

SOL 1.5.134 *Given 132 kV transmission line connected to cable as shown in figure



Characteristics impedance of line and cable are 400 Ωand 80 Ω

250 kV surge travels from A to B than

(a) We have to calculate voltage surge at C.

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(b) Reflected component of surge when reaches A.

(c) Surge current in cable BC

$V_i = 250\,\text{kV},\ Z_{C1} = 400\,\Omega,\ Z_{C2} = 80\,\Omega$

(a) Voltage surge at C

$$V_t = \frac{Z \times Z_{C2}}{Z_{C1} + Z_{C2}} \times V_i = \frac{2 \times 80}{400 + 80} \times 250 = 83.34\,\text{kV}$$

(b) Reflected voltage at A

$$V_r = \left(\frac{Z_{C2} - Z_{C1}}{Z_{C2} + Z_{C1}}\right) V_i = \frac{80 - 400}{400 + 80} \times 250 = -166.67\ \text{kV}$$

(c) Surge current in cable BC

$$I_t = I_i + I_r = I_i - \alpha I_i$$
$$= (1 - \alpha)\, I_i, \text{ Here } \alpha = \frac{Z_{C2} - Z_{C1}}{Z_{C2} + Z_{C1}}$$
$$I_t = \left(1 - \frac{Z_{C2} - Z_{C1}}{Z_{C2} + Z_{C1}}\right)\frac{V_i}{Z_{C1}} = \left(1 + \frac{320}{480}\right)\frac{250}{400}$$
$$= \left(1 + \frac{4}{6}\right)\frac{25}{40} = 1.04\ \text{kAmp}$$

SOL 1.5.135 *We have to draw reactance diagram for given Y_{Bus} matrix

$$Y_{\text{Bus}} = j\begin{bmatrix} -6 & 2 & 2.5 & 0 \\ 2 & -10 & 2.5 & 4 \\ 2.5 & 2.5 & -9 & 4 \\ 0 & 4 & 4 & -8 \end{bmatrix}$$

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$\because$ It is 4×4 matrix (admittance matrix) as

$$Y_{\text{Bus}} = \begin{bmatrix} y_{11} & y_{12} & y_{13} & y_{14} \\ y_{21} & y_{22} & y_{23} & y_{24} \\ y_{31} & y_{32} & y_{33} & y_{34} \\ y_{41} & y_{42} & y_{43} & y_{44} \end{bmatrix}$$

Here diagonal elements

$$y_{11} = y_{10} + y_{12} + y_{13} + y_{14} = -6j \quad \ldots(1)$$
$$y_{22} = y_{20} + y_{21} + y_{23} + y_{24} = -10j \quad \ldots(2)$$
$$y_{33} = y_{30} + y_{31} + y_{32} + y_{34} = -9j \quad \ldots(3)$$
$$y_{44} = y_{40} + y_{41} + y_{42} + y_{43} = -9j \quad \ldots(4)$$

and diagonal elements

$$\left.\begin{aligned} y_{12} = y_{21} = -y_{12} = 2j \\ y_{13} = y_{31} = -y_{13} = 2.5j \\ y_{14} = y_{41} = -y_{14} = 0j \\ y_{23} = y_{32} = -y_{23} = 2.5j \\ y_{24} = y_{42} = -y_{24} = 4j \\ y_{34} = y_{34} = 4j \end{aligned}\right\} \quad \ldots..(5)$$

from equation (1) $y_{10} = y_{11} - y_{12} - y_{13} - y_{14} = -6j + 2j + 2.5j + 0j = -1.5j$

Same as from equation (2)

$$y_{20} = y_{22} - y_{21} - y_{23} - y_{24} = -10j + 2j + 2.5j + 4j = -1.5j$$

from equation (3) $y_{30} = y_{33} - y_{31} - y_{32} - y_{34} = -9j + 2.5j + 2.5j + 4j = 0$

from equation (4) $y_{40} = y_{44} - y_{41} - y_{42} - y_{43} = -8j + 0 + 4j + 4j = 0$

Now we have to draw the reactance diagram as follows

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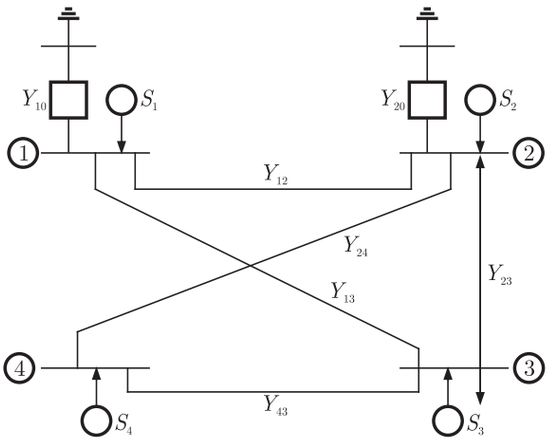

SOL 1.5.136 *Given synchronous generator is connected to infinite bus through loss less double circuit line

$$P_d = 1\angle 30^\circ \text{ pu}$$

sudden fault reduces the peak power transmitted to 0.5 pu

after clearance of fault, peak power = 1.5 pu

Critical clearing angle (δ_{cr})= ?

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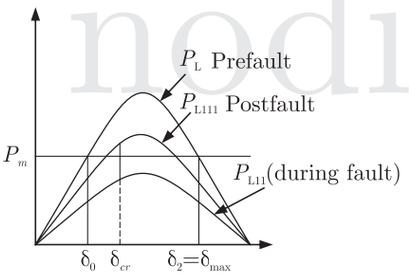

$$\delta_0 = 30^\circ = 0.52 \text{ rad}$$

From equal area criteria

$$\int_{\delta_0}^{\delta_{cr}} (P_{L11} - P_{\max 11}\sin\delta)\,d\delta = \int_{\delta_{cr}}^{\delta_{\max}} (P_{\max 111}\sin\delta - P_m)\,d\delta \qquad ...(1)$$

Where $$\delta_{\max} = \pi - \sin^{-1}\left(\frac{P_m}{P_{\max 111}}\right)$$

$$\delta_{\max} = \pi - 0.8729 = 2.41 \text{ rad}$$

By integrating equation (1)

$$[P_m\delta + P_{\max 11}\cos\delta]_{\delta_{cr}}^{\delta_{\max}} - P_{\max 111}(\cos\delta_{\max} - \cos\delta_{cr}) = 0$$

$$\Rightarrow \quad P_m(\delta_{cr} - \delta_\sigma) + P_{\max 11}(\cos\delta_{cr} - \cos\delta_0) + P_m(\delta_{\max} - \delta_{cr}) + P_{\max 111}(\cos\delta_{\max} - \cos\delta_{cr}) = 0$$

$$\Rightarrow \quad \cos\delta_{cr} = \frac{P_m(\delta_{\max} - \delta_0) - P_{\max 11}\cos\delta_0 + P_{\max 111}\cos\delta_{\max}}{P_{\max 111} - P_{\max 11}}$$

$$= \frac{1(2.41 - 0.52) - 0.5\cos(0.52) + 1.5\cos(2.41)}{1.5 - 0.5}$$

$$\cos\delta_{cr} = 0.35$$

$$\delta_{cr} = \cos^{-1}0.35 = 1.21 \text{ rad}$$

SOL 1.5.137 *Given: L - G fault on unloaded generator

$Z_0 = j0.15$, $Z_1 = j0.25$, $Z_2 = j0.25$ pu, $Z_n = j0.05$ pu

$$V_{\text{prefault}} = 1 \text{ pu}$$

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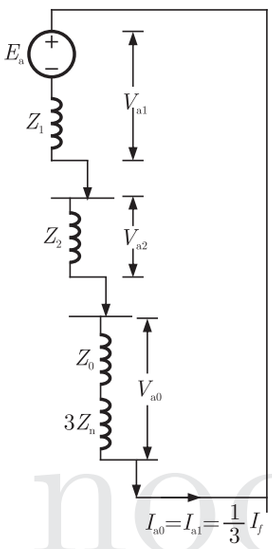
$$I_f = ?$$

Fault Current

$$I_f = 3I_{a1} = \frac{3V_{\text{prefault}}}{Z_1 + Z_2 + Z_0 + 3Z_n} = \frac{3 \times 1}{(j0.25 + j0.25 + j0.15) + 3(j.05)}$$

$$= \frac{3}{0.80j} = -3.75j$$

Sequence network is being drawn as follows



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SOL 1.5.138 *Given power system has two generator

Generator - 1; $C_1 = 0.006P_{G1}^2 + 8P_{G1} + 350$

Generator - 2; $C_2 = 0.009P_{G2}^2 + 7P_{G2} + 400$

Generator Limits are $100 \text{ MW} \le P_{G1} \le 650 \text{ MW}$

$50 \text{ MW} \le P_{G2} \le 500 \text{ MW}$

$P_{G1} + P_{G2} = 600 \text{ MW}$, $P_{G1}, P_{G2} = ?$ For optimal generation

We know for optimal Generation

$$\frac{\partial C_1}{\partial P_{G1}} = \frac{\partial C_2}{\partial P_{G2}} \quad \ldots(1)$$

$$\frac{\partial C_1}{\partial P_{G1}} = 0.012P_{G1} + 8$$

$$\frac{\partial C_2}{\partial P_{G2}} = 0.018P_{G2} + 7$$

from equation (1)

$$0.012P_{G1} + 8 = 0.018P_{G2} + 7$$

$$0.012P_{G1} - 0.018P_{G2} = -1 \quad \ldots(2)$$

$$P_{G1} + P_{G2} = 600 \quad \ldots(3)$$

From equation (2)

$$0.012P_{G1} - 0.018(600 - P_{G1}) = -1$$

$$\Rightarrow \quad 0.03P_{G1} = 9.8$$

$$\Rightarrow \quad P_{G1} = 326.67 \text{ MW}$$

$$P_{G2} = 600 - P_{G1} = 600 - 326.67 = 273.33 \text{ MW}$$

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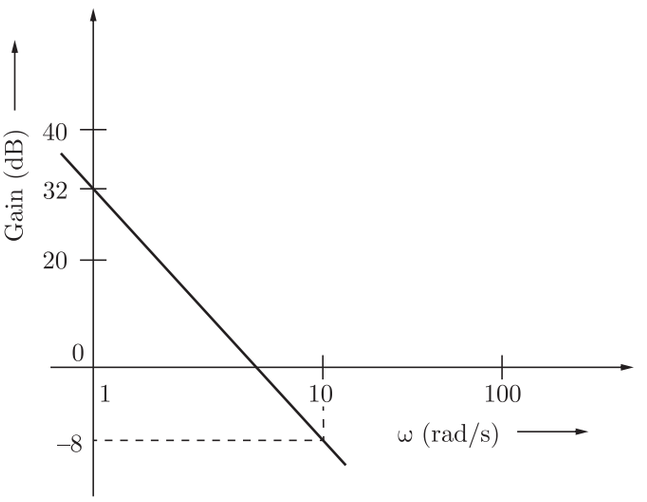
6

CONTROL SYSTEMS

YEAR 2013 ONE MARK

MCQ 1.6.1 The Bode plot of a transfer function $G(s)$ is shown in the figure below.

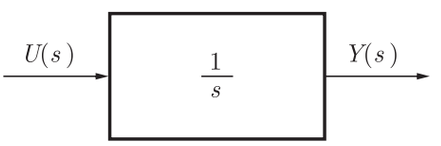


The gain $\left(20\log|G(s)|\right)$ is 32 dB and -8 dB at 1 rad/s and 10 rad/s respectively. The phase is negative for all ω. Then $G(s)$ is

(A) $\dfrac{39.8}{s}$ (B) $\dfrac{39.8}{s^2}$

(C) $\dfrac{32}{s}$ (D) $\dfrac{32}{s^2}$

MCQ 1.6.2 Assuming zero initial condition, the response $y(t)$ of the system given below to a unit step input $u(t)$ is

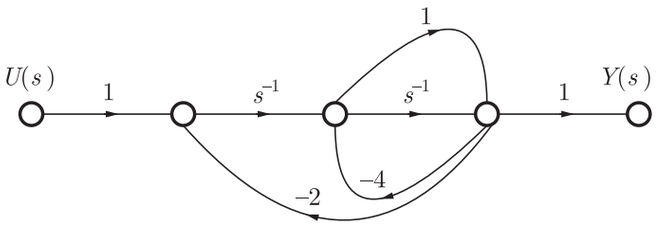


(A) $u(t)$ (B) $tu(t)$

(C) $\dfrac{t^2}{2}u(t)$ (D) $e^{-t}u(t)$

YEAR 2013 TWO MARKS

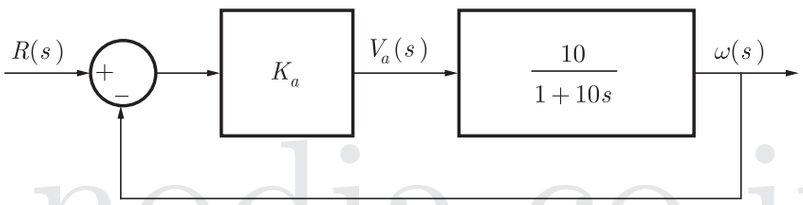
MCQ 1.6.3 The signal flow graph for a system is given below. The transfer function $\dfrac{Y(s)}{U(s)}$ for this system is



(A) $\frac{s+1}{5s^2+6s+2}$ (B) $\frac{s+1}{s^2+6s+2}$

(C) $\frac{s+1}{s^2+4s+2}$ (D) $\frac{1}{5s^2+6s+2}$

MCQ 1.6.4 The open-loop transfer function of a dc motor is given as $\frac{\omega(s)}{V_a(s)} = \frac{10}{1+10s}$. When connected in feedback as shown below, the approximate value of K_a that will reduce the time constant of the closed loop system by one hundred times as compared to that of the open-loop system is



(A) 1 (B) 5

(C) 10 (D) 100

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Common Data Questions: 5 & 6

The state variable formulation of a system is given as

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}-2 & 0\\ 0 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}1\\ 1\end{bmatrix}u,\ x_1(0)=0,\ x_2(0)=0 \text{ and } y = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

MCQ 1.6.5 The response $y(t)$ to the unit step input is

(A) $\frac{1}{2} - \frac{1}{2}e^{-2t}$ (B) $1 - \frac{1}{2}e^{-2t} - \frac{1}{2}e^{-t}$

(C) $e^{-2t} - e^{-t}$ (D) $1 - e^{-t}$

MCQ 1.6.6 The system is

(A) controllable but not observable

(B) not controllable but observable

(C) both controllable and observable

(D) both not controllable and not observable

YEAR 2012 TWO MARKS

MCQ 1.6.7 The state variable description of an LTI system is given by

$$\begin{pmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{pmatrix} = \begin{pmatrix}0 & a_1 & 0\\ 0 & 0 & a_2\\ a_3 & 0 & 0\end{pmatrix}\begin{pmatrix}x_1\\ x_2\\ x_3\end{pmatrix} + \begin{pmatrix}0\\ 0\\ 1\end{pmatrix}u$$

$$y = \begin{pmatrix}1 & 0 & 0\end{pmatrix}\begin{pmatrix}x_1\\ x_2\\ x_3\end{pmatrix}$$

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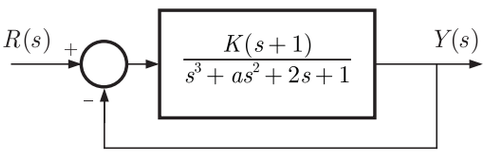
where y is the output and u is the input. The system is controllable for

(A) $a_1 \neq 0, a_2 = 0, a_3 \neq 0$ (B) $a_1 = 0, a_2 \neq 0, a_3 \neq 0$

(C) $a_1 = 0, a_3 \neq 0, a_3 = 0$ (D) $a_1 \neq 0, a_2 \neq 0, a_3 = 0$

MCQ 1.6.8 The feedback system shown below oscillates at 2 rad/s when



(A) $K = 2$ and $a = 0.75$ (B) $K = 3$ and $a = 0.75$

(C) $K = 4$ and $a = 0.5$ (D) $K = 2$ and $a = 0.5$

Statement for Linked Answer Questions 9 and 10 :

The transfer function of a compensator is given as

$$G_c(s) = \frac{s+a}{s+b}$$

MCQ 1.6.9 $G_c(s)$ is a lead compensator if

(A) $a = 1, b = 2$ (B) $a = 3, b = 2$

(C) $a = -3, b = -1$ (D) $a = 3, b = 1$

MCQ 1.6.10 The phase of the above lead compensator is maximum at

(A) $\sqrt{2}$ rad/s (B) $\sqrt{3}$ rad/s

(C) $\sqrt{6}$ rad/s (D) $1/\sqrt{3}$ rad/s

YEAR 2011 ONE MARK

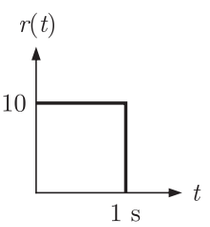
MCQ 1.6.11 The frequency response of a linear system $G(j\omega)$ is provided in the tubular form below

$\lvert G(j\omega)\rvert$	1.3	1.2	1.0	0.8	0.5	0.3
$\angle G(j\omega)$	-130°	-140°	-150°	-160°	-180°	-200°

(A) 6 dB and 30° (B) 6 dB and -30°

(C) -6 dB and 30° (D) -6 dB and -30°

MCQ 1.6.12 The steady state error of a unity feedback linear system for a unit step input is 0.1. The steady state error of the same system, for a pulse input $r(t)$ having a magnitude of 10 and a duration of one second, as shown in the figure is



(A) 0 (B) 0.1

(C) 1 (D) 10

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MCQ 1.6.13 An open loop system represented by the transfer function

$$G(s) = \frac{(s-1)}{(s+2)(s+3)} \text{ is}$$

(A) Stable and of the minimum phase type

(B) Stable and of the non–minimum phase type

(C) Unstable and of the minimum phase type

(D) Unstable and of non–minimum phase type

YEAR 2011 TWO MARKS

MCQ 1.6.14 The open loop transfer function $G(s)$ of a unity feedback control system is given as

$$G(s) = \frac{K\left(s+\frac{2}{3}\right)}{s^2(s+2)}$$

From the root locus, at can be inferred that when K tends to positive infinity,

(A) Three roots with nearly equal real parts exist on the left half of the s-plane

(B) One real root is found on the right half of the s-plane

(C) The root loci cross the $j\omega$ axis for a finite value of $K; K \neq 0$

(D) Three real roots are found on the right half of the s-plane

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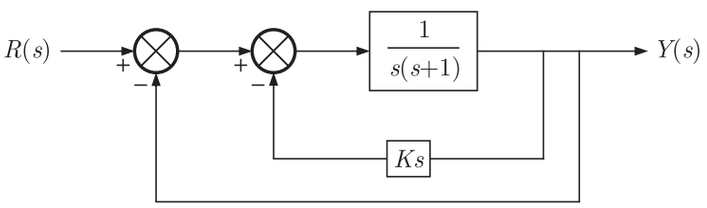
MCQ 1.6.15 A two loop position control system is shown below



The gain K of the Tacho-generator influences mainly the

(A) Peak overshoot

(B) Natural frequency of oscillation

(C) Phase shift of the closed loop transfer function at very low frequencies ($\omega \to 0$)

(D) Phase shift of the closed loop transfer function at very high frequencies ($\omega \to \infty$)

YEAR 2010 TWO MARKS

MCQ 1.6.16 The frequency response of $G(s) = \frac{1}{s(s+1)(s+2)}$ plotted in the complex $G(j\omega)$ plane (for $0 < \omega < \infty$) is

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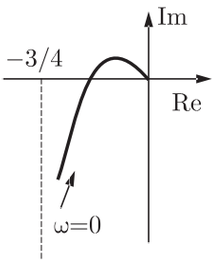
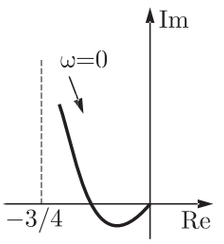
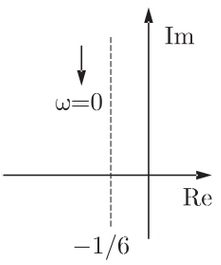
(A)



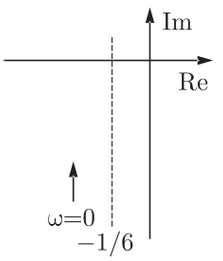
(B)



(C)



(D)



MCQ 1.6.17 The system $\dot{X} = AX + Bu$ with $A = \begin{bmatrix} -1 & 2 \\ 0 & 2 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ is

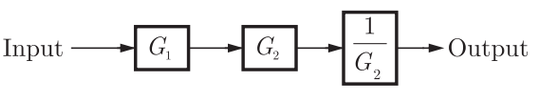
(A) Stable and controllable
(B) Stable but uncontrollable
(C) Unstable but controllable
(D) Unstable and uncontrollable

MCQ 1.6.18 The characteristic equation of a closed-loop system is $s(s+1)(s+3)k(s+2) = 0, k > 0$. Which of the following statements is true ?

(A) Its root are always real
(B) It cannot have a breakaway point in the range $-1 < \mathrm{Re}[s] < 0$
(C) Two of its roots tend to infinity along the asymptotes $\mathrm{Re}[s] = -1$
(D) It may have complex roots in the right half plane.

YEAR 2009 ONE MARK

MCQ 1.6.19 The measurement system shown in the figure uses three sub-systems in cascade whose gains are specified as $G_1, G_2, 1/G_3$. The relative small errors associated with each respective subsystem G_1, G_2 and G_3 are $\varepsilon_1, \varepsilon_2$ and ε_3. The error associated with the output is :



(A) $\varepsilon_1 + \varepsilon_2 + \dfrac{1}{\varepsilon_3}$
(B) $\dfrac{\varepsilon_1 \varepsilon_2}{\varepsilon_3}$
(C) $\varepsilon_1 + \varepsilon_2 - \varepsilon_3$
(D) $\varepsilon_1 + \varepsilon_2 + \varepsilon_3$

MCQ 1.6.20 The polar plot of an open loop stable system is shown below. The closed loop system is

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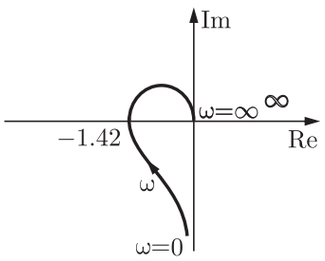

(A) always stable

(B) marginally stable

(C) un-stable with one pole on the RH s-plane

(D) un-stable with two poles on the RH s-plane

MCQ 1.6.21 The first two rows of Routh's tabulation of a third order equation are as follows.

s^3	2	2
s^2	4	4

This means there are

(A) Two roots at $s = \pm j$ and one root in right half s-plane

(B) Two roots at $s = \pm j2$ and one root in left half s-plane

(C) Two roots at $s = \pm j2$ and one root in right half s-plane

(D) Two roots at $s = \pm j$ and one root in left half s-plane

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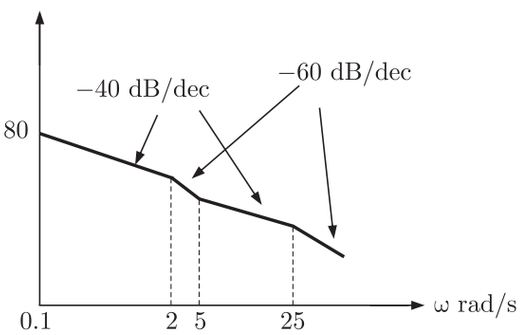
MCQ 1.6.22 The asymptotic approximation of the log-magnitude v/s frequency plot of a system containing only real poles and zeros is shown. Its transfer function is



(A) $\dfrac{10(s+5)}{s(s+2)(s+25)}$

(B) $\dfrac{1000(s+5)}{s^2(s+2)(s+25)}$

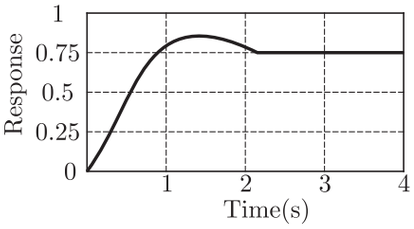
(C) $\dfrac{100(s+5)}{s(s+2)(s+25)}$

(D) $\dfrac{80(s+5)}{s^2(s+2)(s+25)}$

YEAR 2009 TWO MARKS

MCQ 1.6.23 The unit-step response of a unity feed back system with open loop transfer function $G(s) = K/((s+1)(s+2))$ is shown in the figure.

The value of K is



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(A) 0.5 (B) 2

(C) 4 (D) 6

MCQ 1.6.24 The open loop transfer function of a unity feed back system is given by $G(s) = (e^{-0.1s})/s$. The gain margin of the is system is

(A) 11.95 dB (B) 17.67 dB

(C) 21.33 dB (D) 23.9 dB

Common Data for Question 25 and 26 :

A system is described by the following state and output equations

$$\frac{dx_1(t)}{dt} = -3x_1(t) + x_2(t) + 2u(t)$$

$$\frac{dx_2(t)}{dt} = -2x_2(t) + u(t)$$

$$y(t) = x_1(t)$$

when $u(t)$ is the input and $y(t)$ is the output

MCQ 1.6.25 The system transfer function is

(A) $\frac{s+2}{s^2+5s-6}$ (B) $\frac{s+3}{s^2+5s+6}$

(C) $\frac{2s+5}{s^2+5s+6}$ (D) $\frac{2s-5}{s^2+5s-6}$

MCQ 1.6.26 The state-transition matrix of the above system is

(A) $\begin{bmatrix} e^{-3t} & 0 \\ e^{-2t}+e^{-3t} & e^{-2t} \end{bmatrix}$ (B) $\begin{bmatrix} e^{-3t} & e^{-2t}-e^{-3t} \\ 0 & e^{-2t} \end{bmatrix}$

(C) $\begin{bmatrix} e^{-3t} & e^{-2t}+e^{-3t} \\ 0 & e^{-2t} \end{bmatrix}$ (D) $\begin{bmatrix} e^{3t} & e^{-2t}-e^{-3t} \\ 0 & e^{-2t} \end{bmatrix}$

YEAR 2008 ONE MARK

MCQ 1.6.27 A function $y(t)$ satisfies the following differential equation :

$$\frac{dy(t)}{dt} + y(t) = \delta(t)$$

where $\delta(t)$ is the delta function. Assuming zero initial condition, and denoting the unit step function by $u(t)$,$y(t)$ can be of the form

(A) e^t (B) e^{-t}

(C) $e^t u(t)$ (D) $e^{-t} u(t)$

YEAR 2008 TWO MARK

MCQ 1.6.28 The transfer function of a linear time invariant system is given as

$$G(s) = \frac{1}{s^2+3s+2}$$

The steady state value of the output of the system for a unit impulse input applied at time instant $t = 1$ will be

(A) 0 (B) 0.5

(C) 1 (D) 2

MCQ 1.6.29 The transfer functions of two compensators are given below :

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$C_1 = \dfrac{10(s+1)}{(s+10)}$, $C_2 = \dfrac{s+10}{10(s+1)}$

Which one of the following statements is correct ?

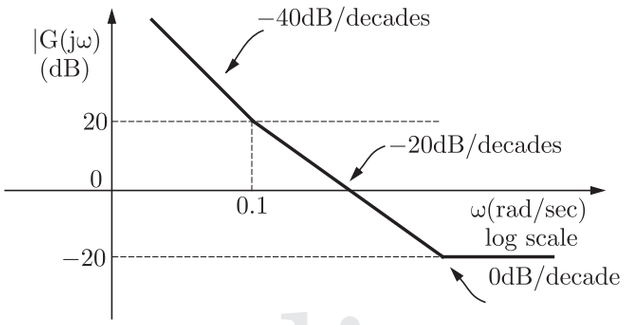
(A) C_1 is lead compensator and C_2 is a lag compensator

(B) C_1 is a lag compensator and C_2 is a lead compensator

(C) Both C_1 and C_2 are lead compensator

(D) Both C_1 and C_2 are lag compensator

MCQ 1.6.30 The asymptotic Bode magnitude plot of a minimum phase transfer function is shown in the figure :

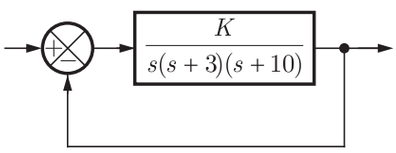


This transfer function has

(A) Three poles and one zero (B) Two poles and one zero

(C) Two poles and two zero (D) One pole and two zeros

MCQ 1.6.31 Figure shows a feedback system where $K > 0$



The range of K for which the system is stable will be given by

(A) $0 < K < 30$ (B) $0 < K < 39$

(C) $0 < K < 390$ (D) $K > 390$

MCQ 1.6.32 The transfer function of a system is given as

$$\frac{100}{s^2 + 20s + 100}$$

The system is

(A) An over damped system (B) An under damped system

(C) A critically damped system (D) An unstable system

Statement for Linked Answer Question 27 and 28.

The state space equation of a system is described by $\dot{X} = AX + Bu, Y = CX$ where X is state vector, u is input, Y is output and

$$A = \begin{bmatrix} 0 & 1 \\ 0 & -2 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, C = [1 \quad 0]$$

MCQ 1.6.33 The transfer function G(s) of this system will be

(A) $\dfrac{s}{(s+2)}$ (B) $\dfrac{s+1}{s(s-2)}$

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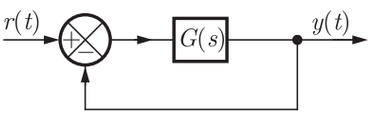
(C) $\frac{s}{(s-2)}$ (D) $\frac{1}{s(s+2)}$

MCQ 1.6.34 A unity feedback is provided to the above system $G(s)$ to make it a closed loop system as shown in figure.



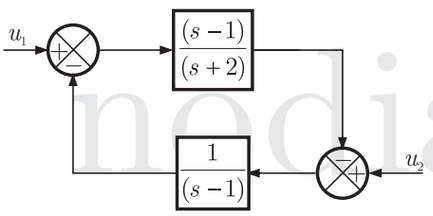
For a unit step input $r(t)$, the steady state error in the input will be

(A) 0 (B) 1

(C) 2 (D) 3

YEAR 2007 ONE MARK

MCQ 1.6.35 The system shown in the figure is



(A) Stable

(B) Unstable

(C) Conditionally stable

(D) Stable for input u_1, but unstable for input u_2

YEAR 2007 TWO MARKS

MCQ 1.6.36 If $x = \text{Re}[G(j\omega)]$, and $y = \text{Im}[G(j\omega)]$ then for ω " 0^+, the Nyquist plot for $G(s) = 1/s(s+1)(s+2)$ is

(A) $x = 0$ (B) $x = -3/4$

(C) $x = y - 1/6$ (D) $x = y/\sqrt{3}$

MCQ 1.6.37 The system $900/s(s+1)(s+9)$ is to be such that its gain-crossover frequency becomes same as its uncompensated phase crossover frequency and provides a 45c phase margin. To achieve this, one may use

(A) a lag compensator that provides an attenuation of 20 dB and a phase lag of 45c at the frequency of $3\sqrt{3}$ rad/s

(B) a lead compensator that provides an amplification of 20 dB and a phase lead of 45c at the frequency of 3 rad/s

(C) a lag-lead compensator that provides an amplification of 20 dB and a phase lag of 45c at the frequency of $\sqrt{3}$ rad/s

(D) a lag-lead compensator that provides an attenuation of 20 dB and phase lead of 45c at the frequency of 3 rad/s

MCQ 1.6.38 If the loop gain K of a negative feed back system having a loop transfer function

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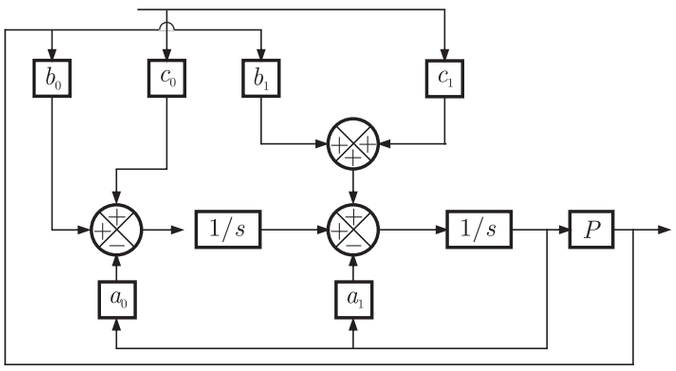
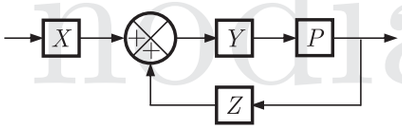
$K(s+3)/(s+8)^2$ is to be adjusted to induce a sustained oscillation then
(A) The frequency of this oscillation must be $4\sqrt{3}$ rad/s
(B) The frequency of this oscillation must be 4 rad/s
(C) The frequency of this oscillation must be 4 or $4\sqrt{3}$ rad/s
(D) Such a K does not exist

MCQ 1.6.39 The system shown in figure below



can be reduced to the form



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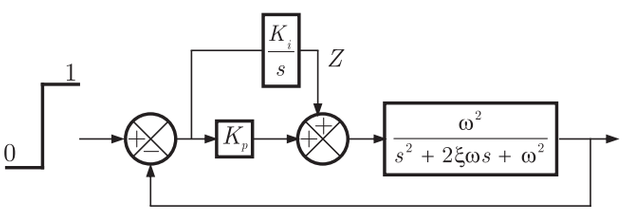
with
(A) $X = c_0 s + c_1, Y = 1/(s^2 + a_0 s + a_1), Z = b_0 s + b_1$
(B) $X = 1, Y = (c_0 s + c_1)/(s^2 + a_0 s + a_1), Z = b_0 s + b_1$
(C) $X = c_1 s + c_0, Y = (b_1 s + b_0)/(s^2 + a_1 s + a_0), Z = 1$
(D) $X = c_1 s + c_0, Y = 1/(s^2 + a_1 s + a), Z = b_1 s + b_0$

MCQ 1.6.40 Consider the feedback system shown below which is subjected to a unit step input. The system is stable and has following parameters $K_p = 4, K_i = 10, \omega = 500$ and $\xi = 0.7$.The steady state value of Z is



(A) 1
(B) 0.25
(C) 0.1
(D) 0

Data for Q.41 and Q.42 are given below. Solve the problems and choose the correct answers.

R-L-C circuit shown in figure

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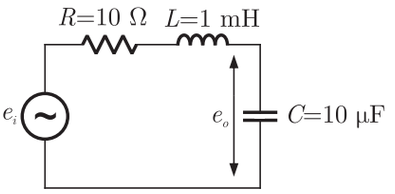


MCQ 1.6.41 For a step-input e_i, the overshoot in the output e_0 will be

(A) 0, since the system is not under damped

(B) 5 %

(C) 16 %

(D) 48 %

MCQ 1.6.42 If the above step response is to be observed on a non-storage CRO, then it would be best have the e_i as a

(A) Step function

(B) Square wave of 50 Hz

(C) Square wave of 300 Hz

(D) Square wave of 2.0 KHz

YEAR 2006 ONE MARK

MCQ 1.6.43 For a system with the transfer function

$$H(s) = \frac{3(s-2)}{4s^2 - 2s + 1},$$

the matrix A in the state space form $\dot{X} = AX + Bu$ is equal to

(A) $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -1 & 2 & -4 \end{bmatrix}$

(B) $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & 2 & -4 \end{bmatrix}$

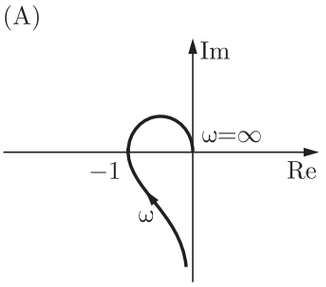
(C) $\begin{bmatrix} 0 & 1 & 0 \\ 3 & -2 & 1 \\ 1 & -2 & 4 \end{bmatrix}$

(D) $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ -1 & 2 & -4 \end{bmatrix}$

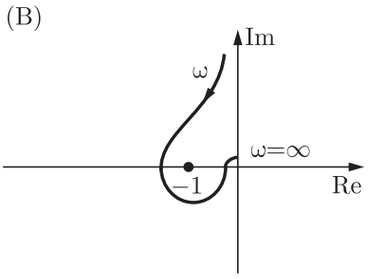
YEAR 2006 TWO MARKS

MCQ 1.6.44 Consider the following Nyquist plots of loop transfer functions over $\omega = 0$ to $\omega = 3$. Which of these plots represent a stable closed loop system ?

(A)



(B)



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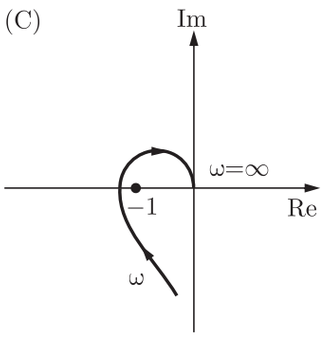
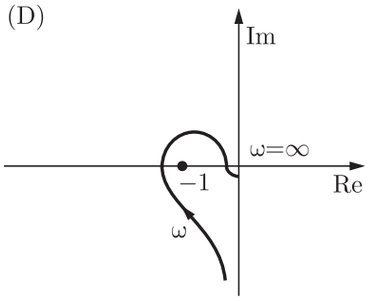
(C)



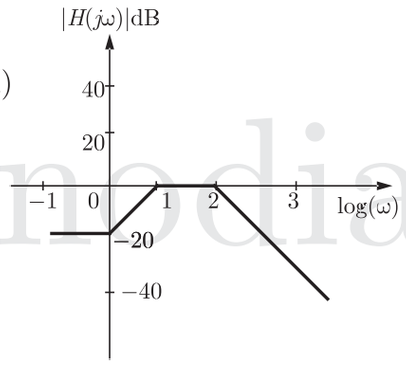
(D)



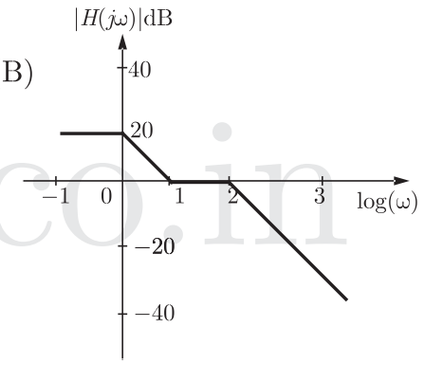
(A) (1) only
(B) all, except (1)
(C) all, except (3)
(D) (1) and (2) only

MCQ 1.6.45 The Bode magnitude plot $H(j\omega) = \dfrac{10^4(1+j\omega)}{(10+j\omega)(100+j\omega)^2}$ is

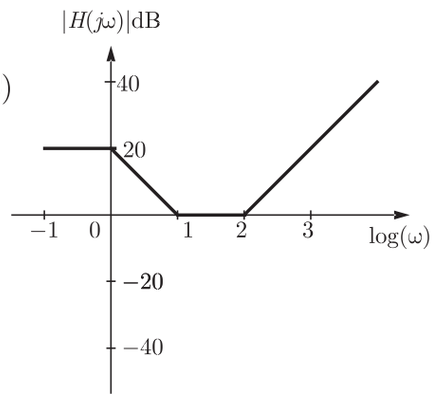
(A)



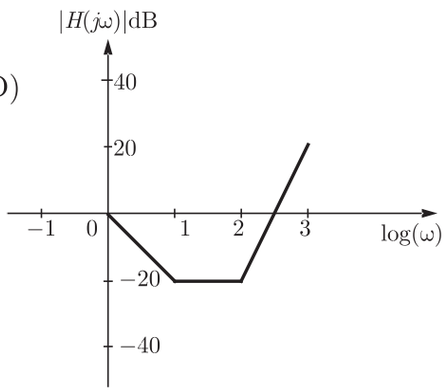
(B)



(C)



(D)



MCQ 1.6.46 A closed-loop system has the characteristic function $(s^2-4)(s+1)+K(s-1)=0$. Its root locus plot against K is

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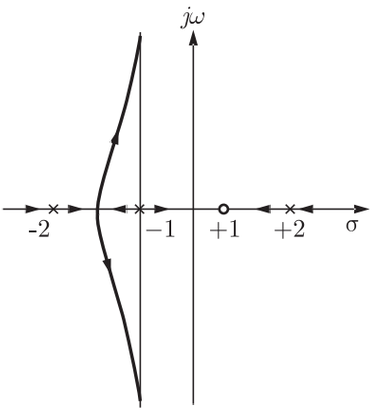
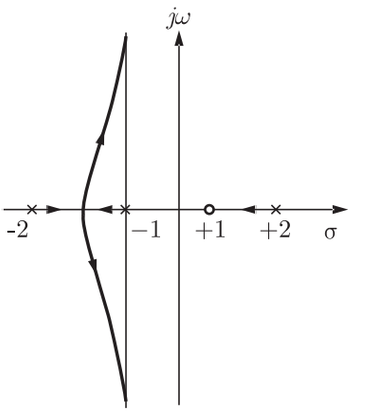
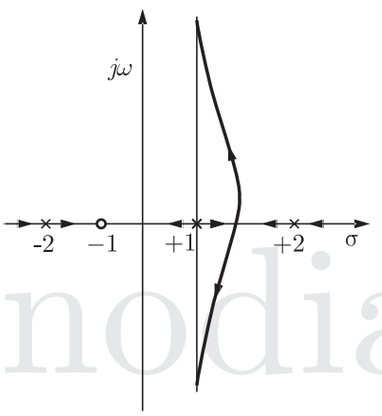
(A)



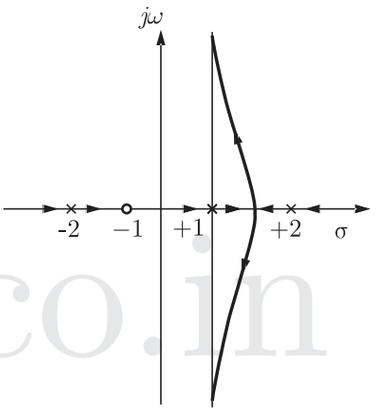
(B)



(C)



(D)



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MCQ 1.6.47 A system with zero initial conditions has the closed loop transfer function.

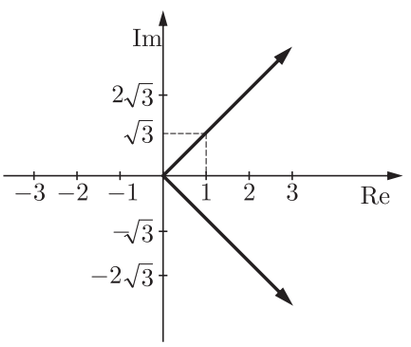
$$T(s) = \frac{s^2+4}{(s+1)(s+4)}$$

The system output is zero at the frequency

(A) 0.5 rad/sec (B) 1 rad/sec

(C) 2 rad/sec (D) 4 rad/sec

MCQ 1.6.48 Figure shows the root locus plot (location of poles not given) of a third order system whose open loop transfer function is



(A) $\frac{K}{s^3}$ (B) $\frac{K}{s^2(s+1)}$

(C) $\frac{K}{s(s^2+1)}$ (D) $\frac{K}{s(s^2-1)}$

MCQ 1.6.49 The gain margin of a unity feed back control system with the open loop transfer

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function $G(s) = \dfrac{(s+1)}{s^2}$ is

(A) 0 (B) $\dfrac{1}{\sqrt{2}}$

(C) $\sqrt{2}$ (D) 3

YEAR 2005 TWO MARKS

MCQ 1.6.50 A unity feedback system, having an open loop gain

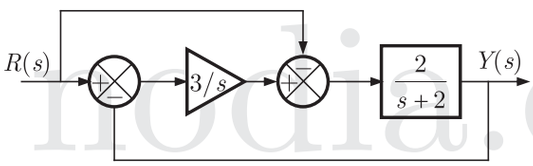
$$G(s)H(s) = \frac{K(1-s)}{(1+s)},$$

becomes stable when

(A) $|K| > 1$ (B) $K > 1$

(C) $|K| < 1$ (D) $K < -1$

MCQ 1.6.51 When subject to a unit step input, the closed loop control system shown in the figure will have a steady state error of



(A) -1.0 (B) -0.5

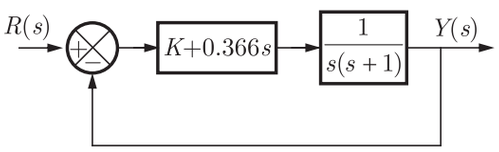
(C) 0 (D) 0.5

MCQ 1.6.52 In the $G(s)H(s)$-plane, the Nyquist plot of the loop transfer function $G(s)H(s) = \frac{\pi e^{-0.25s}}{s}$ passes through the negative real axis at the point

(A) $(-0.25, j0)$ (B) $(-0.5, j0)$

(C) 0 (D) 0.5

MCQ 1.6.53 If the compensated system shown in the figure has a phase margin of 60c at the crossover frequency of 1 rad/sec, then value of the gain K is



(A) 0.366 (B) 0.732

(C) 1.366 (D) 2.738

Data for Q.54 and Q.55 are given below. Solve the problem and choose the correct answer.

A state variable system $\dot{X}(t) = \begin{bmatrix} 0 & 1 \\ 0 & -3 \end{bmatrix} X(t) + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(t)$ with the initial condition $X(0) = [-1, \ 3]^T$ and the unit step input $u(t)$ has

MCQ 1.6.54 The state transition matrix

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(A) $\begin{bmatrix} 1 & \frac{1}{3}(1-e^{-3t}) \\ 0 & e^{-3t} \end{bmatrix}$ (B) $\begin{bmatrix} 1 & \frac{1}{3}(e^{-t}-e^{-3t}) \\ 0 & e^{-t} \end{bmatrix}$

(C) $\begin{bmatrix} 1 & \frac{1}{3}(e^{3-t}-e^{-3t}) \\ 0 & e^{-3t} \end{bmatrix}$ (D) $\begin{bmatrix} 1 & (1-e^{-t}) \\ 0 & e^{-t} \end{bmatrix}$

MCQ 1.6.55 The state transition equation

(A) $X(t) = \begin{bmatrix} t-e^{-t} \\ e^{-t} \end{bmatrix}$ (B) $X(t) = \begin{bmatrix} 1-e^{-t} \\ 3e^{-3t} \end{bmatrix}$

(C) $X(t) = \begin{bmatrix} t-e^{3t} \\ 3e^{-3t} \end{bmatrix}$ (D) $X(t) = \begin{bmatrix} t-e^{-3t} \\ e^{-t} \end{bmatrix}$

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MCQ 1.6.56 The Nyquist plot of loop transfer function $G(s)H(s)$ of a closed loop control system passes through the point $(-1, j0)$ in the $G(s)H(s)$plane. The phase margin of the system is

(A) 0c (B) 45c

(C) 90c (D) 180c

MCQ 1.6.57 Consider the function,

$$F(s) = \frac{5}{s(s^2+3s+2)}$$

where $F(s)$ is the Laplace transform of the of the function $f(t)$. The initial value of $f(t)$ is equal to

(A) 5 (B) $\frac{5}{2}$

(C) $\frac{5}{3}$ (D) 0

MCQ 1.6.58 For a tachometer, if $\theta(t)$ is the rotor displacement in radians, $e(t)$ is the output voltage and K_t is the tachometer constant in V/rad/sec, then the transfer function, $\frac{E(s)}{Q(s)}$ will be

(A) $K_t s^2$ (B) K_t/s

(C) $K_t s$ (D) K_t

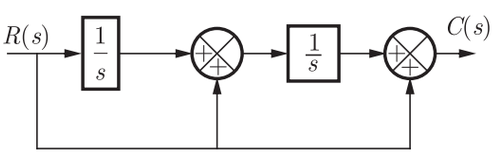
YEAR 2004 TWO MARKS

MCQ 1.6.59 For the equation, $s^3 - 4s^2 + s + 6 = 0$ the number of roots in the left half of s -plane will be

(A) Zero (B) One

(C) Two (D) Three

MCQ 1.6.60 For the block diagram shown, the transfer function $\frac{C(s)}{R(s)}$ is equal to



(A) $\frac{s^2+1}{s^2}$ (B) $\frac{s^2+s+1}{s^2}$

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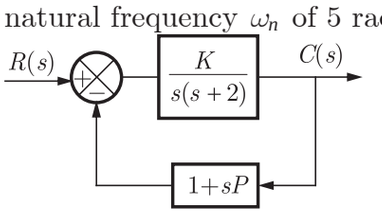
(C) $\frac{s^2+s+1}{s}$ (D) $\frac{1}{s^2+s+1}$

MCQ 1.6.61 The state variable description of a linear autonomous system is, $\dot{X} = AX$ where X is the two dimensional state vector and A is the system matrix given by $A = \begin{bmatrix} 0 & 2 \\ -2 & 0 \end{bmatrix}$. The roots of the characteristic equation are

(A) -2 and $+2$ (B) $-j2$ and $+j2$

(C) -2 and -2 (D) $+2$ and $+2$

MCQ 1.6.62 The block diagram of a closed loop control system is given by figure. The values of K and P such that the system has a damping ratio of 0.7 and an undamped natural frequency ω_n of 5 rad/sec, are respectively equal to



(A) 20 and 0.3 (B) 20 and 0.2

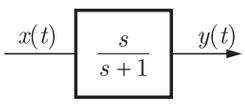
(C) 25 and 0.3 (D) 25 and 0.2

MCQ 1.6.63 The unit impulse response of a second order under-damped system starting from rest is given by $c(t) = 12.5e^{-6t}\sin 8t,\ t \geq 0$. The steady-state value of the unit step response of the system is equal to

(A) 0 (B) 0.25

(C) 0.5 (D) 1.0

MCQ 1.6.64 In the system shown in figure, the input $x(t) = \sin t$. In the steady-state, the response $y(t)$ will be



(A) $\frac{1}{\sqrt{2}}\sin(t-45^\circ)$ (B) $\frac{1}{\sqrt{2}}\sin(t+45^\circ)$

(C) $\sin(t-45^\circ)$ (D) $\sin(t+45^\circ)$

MCQ 1.6.65 The open loop transfer function of a unity feedback control system is given as

$$G(s) = \frac{as+1}{s^2}.$$

The value of 'a' to give a phase margin of 45° is equal to

(A) 0.141 (B) 0.441

(C) 0.841 (D) 1.141

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MCQ 1.6.66 A control system is defined by the following mathematical relationship

$$\frac{d^2x}{dt^2} + 6\frac{dx}{dt} + 5x = 12(1 - e^{-2t})$$

The response of the system as $t \to \infty$ is

(A) $x = 6$ (B) $x = 2$

(C) $x = 2.4$ (D) $x = -2$

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MCQ 1.6.67 A lead compensator used for a closed loop controller has the following transfer function

$$\frac{K\left(1+\frac{s}{a}\right)}{\left(1+\frac{s}{b}\right)}$$

For such a lead compensator

(A) $a < b$ (B) $b < a$

(C) $a > Kb$ (D) $a < Kb$

MCQ 1.6.68 A second order system starts with an initial condition of $\begin{bmatrix}2\\3\end{bmatrix}$ without any external input. The state transition matrix for the system is given by $\begin{bmatrix}e^{-2t} & 0\\0 & e^{-t}\end{bmatrix}$. The state of the system at the end of 1 second is given by

(A) $\begin{bmatrix}0.271\\1.100\end{bmatrix}$ (B) $\begin{bmatrix}0.135\\0.368\end{bmatrix}$

(C) $\begin{bmatrix}0.271\\0.736\end{bmatrix}$ (D) $\begin{bmatrix}0.135\\1.100\end{bmatrix}$

YEAR 2003 TWO MARKS

MCQ 1.6.69 A control system with certain excitation is governed by the following mathematical equation

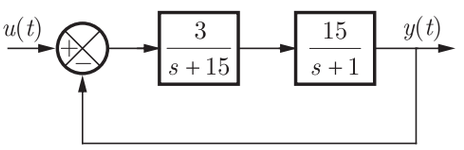
$$\frac{d^2x}{dt^2}+\frac{1}{2}\frac{dx}{dt}+\frac{1}{18}x = 10+5e^{-4t}+2e^{-5t}$$

The natural time constant of the response of the system are

(A) 2 sec and 5 sec (B) 3 sec and 6 sec

(C) 4 sec and 5 sec (D) 1/3 sec and 1/6 sec

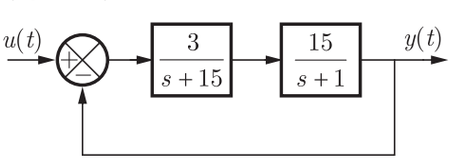
MCQ 1.6.70 The block diagram shown in figure gives a unity feedback closed loop control system. The steady state error in the response of the above system to unit step input is



(A) 25% (B) 0.75 %

(C) 6% (D) 33%

MCQ 1.6.71 The roots of the closed loop characteristic equation of the system shown above (Q-5.55)



(A) -1 and -15 (B) 6 and 10

(C) -4 and -15 (D) -6 and -10

MCQ 1.6.72 The following equation defines a separately excited dc motor in the form of a differential equation

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$$\frac{d^2\omega}{dt}+\frac{B}{J}\frac{d\omega}{dt}+\frac{K^2}{LJ}\omega=\frac{K}{LJ}V_a$$

The above equation may be organized in the state-space form as follows

$$\begin{bmatrix}\frac{d^2\omega}{dt^2}\\ \frac{d\omega}{dt}\end{bmatrix}=P\begin{bmatrix}\frac{d\omega}{dt}\\ \omega\end{bmatrix}+QV_a$$

Where the P matrix is given by

(A) $\begin{bmatrix}-\frac{B}{J} & -\frac{K^2}{LJ}\\ 1 & 0\end{bmatrix}$ (B) $\begin{bmatrix}-\frac{K^2}{LJ} & -\frac{B}{J}\\ 0 & 1\end{bmatrix}$

(C) $\begin{bmatrix}0 & 1\\ -\frac{K^2}{LJ} & -\frac{B}{J}\end{bmatrix}$ (D) $\begin{bmatrix}1 & 0\\ -\frac{B}{J} & -\frac{K^2}{LJ}\end{bmatrix}$

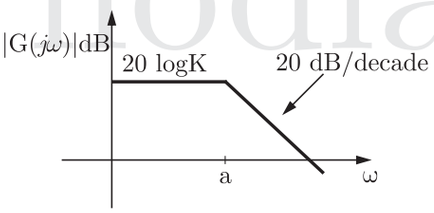
MCQ 1.6.73 The loop gain GH of a closed loop system is given by the following expression $\frac{K}{s(s+2)(s+4)}$

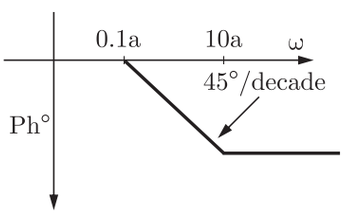
The value of K for which the system just becomes unstable is

(A) $K=6$ (B) $K=8$

(C) $K=48$ (D) $K=96$

MCQ 1.6.74 The asymptotic Bode plot of the transfer function $K/[1+(s/a)]$ is given in figure. The error in phase angle and dB gain at a frequency of $\omega=0.5a$ are respectively

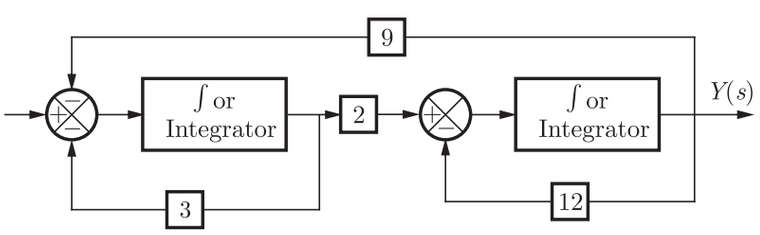




(A) 4.9c, 0.97 dB (B) 5.7c, 3 dB

(C) 4.9c, 3 dB (D) 5.7c, 0.97 dB

MCQ 1.6.75 The block diagram of a control system is shown in figure. The transfer function $G(s)=Y(s)/U(s)$ of the system is



(A) $\frac{1}{18\left(1+\frac{s}{12}\right)\left(1+\frac{s}{3}\right)}$ (B) $\frac{1}{27\left(1+\frac{s}{6}\right)\left(1+\frac{s}{9}\right)}$

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(C) $\dfrac{1}{27\left(1+\frac{s}{12}\right)\left(1+\frac{s}{9}\right)}$ (D) $\dfrac{1}{27\left(1+\frac{s}{9}\right)\left(1+\frac{s}{3}\right)}$

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MCQ 1.6.76 The state transition matrix for the system $\dot{X} = AX$ with initial state $X(0)$ is

(A) $(sI - A)^{-1}$

(B) $e^{At}X(0)$

(C) Laplace inverse of $[(sI - A)^{-1}]$

(D) Laplace inverse of $[(sI - A)^{-1}X(0)]$

YEAR 2002 TWO MARKS

MCQ 1.6.77 For the system $\dot{X} = \begin{bmatrix} 2 & 3 \\ 0 & 5 \end{bmatrix} X + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$, which of the following statements is true ?

(A) The system is controllable but unstable

(B) The system is uncontrollable and unstable

(C) The system is controllable and stable

(D) The system is uncontrollable and stable

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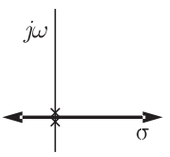
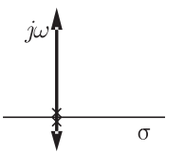
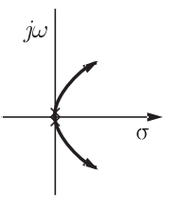
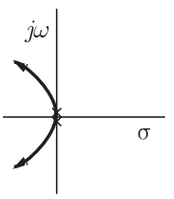
MCQ 1.6.78 A unity feedback system has an open loop transfer function, $G(s) = \dfrac{K}{s^2}$. The root locus plot is

(A) 

(B) 

(C) 

(D) 

MCQ 1.6.79 The transfer function of the system described by

$$\frac{d^2y}{dt^2} + \frac{dy}{dt} = \frac{du}{dt} + 2u$$

with u as input and y as output is

(A) $\dfrac{(s+2)}{(s^2+s)}$ (B) $\dfrac{(s+1)}{(s^2+s)}$

(C) $\dfrac{2}{(s^2+s)}$ (D) $\dfrac{2s}{(s^2+s)}$

MCQ 1.6.80 For the system

$$\dot{X} = \begin{bmatrix} 2 & 0 \\ 0 & 4 \end{bmatrix} X + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u;\ Y = \begin{bmatrix} 4 & 0 \end{bmatrix} X,$$

with u as unit impulse and with zero initial state, the output y, becomes

(A) $2e^{2t}$ (B) $4e^{2t}$

(C) $2e^{4t}$ (D) $4e^{4t}$

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MCQ 1.6.81 The eigen values of the system represented by

$$\dot{X} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ -1 & & & \end{bmatrix} X \text{ are}$$

(A) 0, 0, 0, 0 (B) 1, 1, 1, 1

(C) 0, 0, 0, −1 (D) 1, 0, 0, 0

MCQ 1.6.82 *A single input single output system with y as output and u as input, is described by

$$\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 10y = 5\frac{du}{dt} - 3u$$

for an input $u(t)$ with zero initial conditions the above system produces the same output as with no input and with initial conditions

$$\frac{dy(0^-)}{dt} = -4,\ y(0^-) = 1$$

input $u(t)$ is

(A) $\frac{1}{5}\delta(t) - \frac{7}{25}e^{(3/5)t}u(t)$ (B) $\frac{1}{5}\delta(t) - \frac{7}{25}e^{-3t}u(t)$

(C) $-\frac{7}{25}e^{-(3/5)t}u(t)$ (D) None of these

MCQ 1.6.83 *A system is described by the following differential equation

$$\frac{d^2y}{dt^2} + \frac{dy}{dt} - 2y = u(t)e^{-t}$$

the state variables are given as $x_1 = y$ and $x_2 = \left(\frac{dy}{dt} - y\right)e^t$, the state variable representation of the system is

(A) $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & e^{-t} \\ 0 & e^{-t} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix}u(t)$ (B) $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix}u(t)$

(C) $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & e^{-t} \\ 0 & -1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix}u(t)$ (D) none of these

Common Data Question Q.84-86*.

The open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{2(s+\alpha)}{s(s+2)(s+10)}$$

MCQ 1.6.84 Angles of asymptotes are

(A) 60°,120°,300° (B) 60°,180°,300°

(C) 90°,270°,360° (D) 90°,180°,270°

MCQ 1.6.85 Intercepts of asymptotes at the real axis is

(A) −6 (B) $-\frac{10}{3}$

(C) −4 (D) −8

MCQ 1.6.86 Break away points are

(A) −1.056, −3.471 (B) −2.112, − 6.9433

(C) −1.056, − 6.9433 (D) 1.056, − 6.9433

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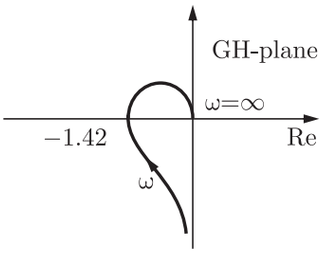
YEAR 2001 ONE MARK

MCQ 1.6.87 The polar plot of a type-1, 3-pole, open-loop system is shown in Figure The closed-loop system is



(A) always stable

(B) marginally stable

(C) unstable with one pole on the right half s-plane

(D) unstable with two poles on the right half s-plane.

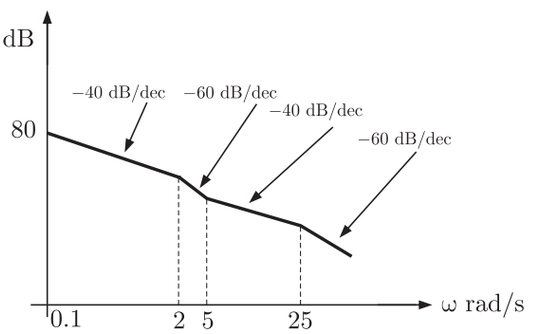
MCQ 1.6.88 Given the homogeneous state-space equation $\dot{x} = \begin{bmatrix} -3 & 1 \\ 0 & -2 \end{bmatrix} x$ the steady state value of $x_{ss} = \lim_{t \to \infty} x(t)$, given the initial state value of $x(0) = \begin{bmatrix} 10 & -10 \end{bmatrix}^T$ is

(A) $x_{ss} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$ (B) $x_{ss} = \begin{bmatrix} -3 \\ -2 \end{bmatrix}$

(C) $x_{ss} = \begin{bmatrix} -10 \\ 10 \end{bmatrix}$ (D) $x_{ss} = \begin{bmatrix} 3 \\ 3 \end{bmatrix}$

YEAR 2001 TWO MARKS

MCQ 1.6.89 The asymptotic approximation of the log-magnitude versus frequency plot of a minimum phase system with real poles and one zero is shown in Figure. Its transfer functions is



(A) $\dfrac{20(s+5)}{s(s+2)(s+25)}$ (B) $\dfrac{10(s+5)}{(s+2)^2(s+25)}$

(C) $\dfrac{20(s+5)}{s^2(s+2)(s+25)}$ (D) $\dfrac{50(s+5)}{s^2(s+2)(s+25)}$

Common Data Question Q.90-93*.

A unity feedback system has an open-loop transfer function of

$$G(s) = \frac{10000}{s(s+10)^2}$$

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MCQ 1.6.90 Determine the magnitude of $G(j\omega)$ in dB at an angular frequency of $\omega = 20$ rad/sec.

(A) 1 dB (B) 0 dB

(C) -2 dB (D) 10 dB

MCQ 1.6.91 The phase margin in degrees is

(A) 90° (B) 36.86°

(C) -36.86° (D) -90°

MCQ 1.6.92 The gain margin in dB is

(A) 13.97 dB (B) 6.02 dB

(C) -13.97 dB (D) None of these

MCQ 1.6.93 The system is

(A) Stable (B) Un-stable

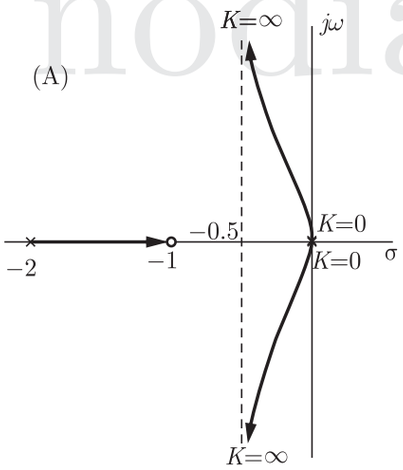
(C) Marginally stable (D) can not determined

MCQ 1.6.94 *For the given characteristic equation

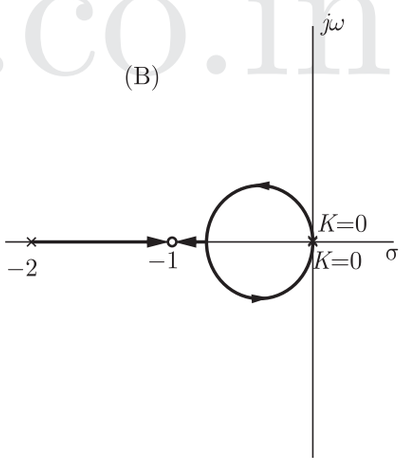
$$s^3 + s^2 + Ks + K = 0$$

The root locus of the system as K varies from zero to infinity is

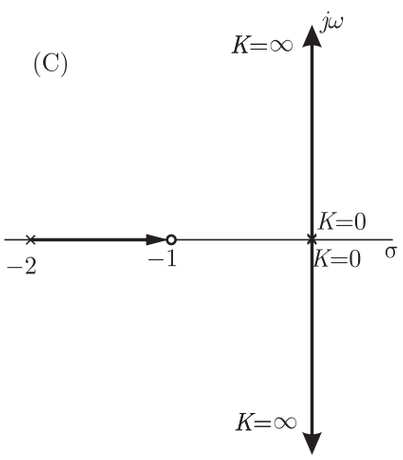
(A)



(B)



(C)



(D) none of these

****

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SOLUTION

SOL 1.6.1 Option (B) is correct.

From the given plot, we obtain the slope as

$$\text{Slope} = \frac{20\log G_2 - 20\log G_1}{\log w_2 - \log w_1}$$

From the figure

$$20\log G_2 = -8\ \text{dB}$$
$$20\log G_1 = 32\ \text{dB}$$

and

$$\omega_1 = 1\ \text{rad/s}$$
$$\omega_2 = 10\ \text{rad/s}$$

So, the slope is

$$\text{Slope} = \frac{-8-32}{\log_{10} - \log_1}$$
$$= -40\ \text{dB/decade}$$

Therefore, the transfer function can be given as

$$G(s) = \frac{k}{S^2}$$

at $\omega = 1$

$$|G(j\omega)| = \frac{k}{|w|^2} = k$$

In decibel,

$$20\log|G(j\omega)| = 20\log k = 32$$

or,

$$k = 10^{32/20} = 39.8$$

Hence, the Transfer function is

$$G(s) = \frac{k}{s^2} = \frac{39.8}{s^2}$$

SOL 1.6.2 Option (B) is correct.

The Laplace transform of unit step fun^n is

$$U(s) = \frac{1}{s}$$

So, the O/P of the system is given as

$$Y(s) = \left(\frac{1}{s}\right)\left(\frac{1}{s}\right)$$
$$= \frac{1}{s^2}$$

For zero initial condition, we check

$$u(t) = \frac{dy(t)}{dt}$$

$$\Rightarrow \quad U(s) = SY(s) - y(0)$$

$$\Rightarrow \quad U(s) = s\left(\frac{1}{s^2}\right) - y(0)$$

or,

$$U(s) = \frac{1}{s} \qquad (y(0) = 0)$$

Hence, the O/P is correct which is

$$Y(s) = \frac{1}{s^2}$$

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its inverse Laplace transform is given by

$$y(t) = tu(t)$$

SOL 1.6.3 Option (A) is correct.

For the given SFG, we have two forward paths

$$P_{k1} = (1)(s^{-1})(s^{-1})(1) = s^{-2}$$
$$P_{k2} = (1)(s^{-1})(1)(1) = s^{-1}$$

since, all the loops are touching to both the paths $P_{k1}$and P_{k2} so,

$$\Delta k_1 = \Delta k_2 = 1$$

Now, we have

$$\Delta = 1 - \text{(sum of individual loops)} + \text{(sum of product of nontouching loops)}$$

Here, the loops are

$$L_1 = (-4)(1) = -4$$
$$L_2 = (-4)(s^{-1}) = 4s^{-1}$$
$$L_3 = (-2)(s^{-1})(s^{-1}) = -2s^{-2}$$
$$L_4 = (-2)(s^{-1})(1) = -2s^{-1}$$

As all the loop L_1, L_2, L_3 and L_4 are touching to each other so,

$$\Delta = 1 - (L_1 + L_2 + L_3 + L_4)$$
$$= 1 - (-4 - 4s^{-1} - 2s^{-2} - 2s^{-1})$$
$$= 5 + 6s^{-1} + 2s^{-2}$$

From Mason's gain formulae

$$\frac{Y(s)}{U(s)} = \frac{\Sigma P_k \Delta_k}{\Delta}$$
$$= \frac{s^{-2} + s^{-1}}{5 + 6s^{-1} + 2s^{-2}}$$
$$= \frac{s+1}{5s^2 + 6s + 2}$$

SOL 1.6.4 Option (C) is correct.

Given, open loop transfer function

$$G(s) = \frac{10K_a}{1 + 10s} = \frac{K_a}{s + \frac{1}{10}}$$

By taking inverse Laplace transform, we have

$$g(t) = e^{-\frac{1}{10}t}$$

Comparing with standard form of transfer function, $Ae^{-t/\tau}$, we get the open loop time constant,

$$\tau_{ol} = 10$$

Now, we obtain the closed loop transfer function for the given system as

$$H(s) = \frac{G(s)}{1 + G(s)} = \frac{10K_a}{1 + 10s + 10K_a}$$
$$= \frac{K_a}{s + (K_a + \frac{1}{10})}$$

By taking inverse laplace transform, we get

$$h(t) = k_a . e^{-(k_a + \frac{1}{10})t}$$

So, the time constant of closed loop system is obtained as

$$\tau_{cl} = \frac{1}{k_a + \frac{1}{10}}$$

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or, $\tau_{cl} = \frac{1}{k_a}$ (approximately)

Now, given that k_a reduces open loop time constant by a factor of 100. i.e.,

$$\tau_{cl} = \frac{\tau_{ol}}{100}$$

or, $$\frac{1}{k_a} = \frac{10}{100}$$

or, $$k_a = 10$$

SOL 1.6.5 Option (A) is correct.

Given, the state variable formulation,

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}-2 & 0\\ 0 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}1\\ 1\end{bmatrix}u \quad \text{....(1)}$$

and $$y = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} \quad \text{....(2)}$$

From Eq. (1) we get

$$\dot{x}_1 = 2x_1 + u$$

Taking Laplace transform

$$sX_1 - x_1(0) = -2X_1 + \frac{1}{s}$$ (Here, X_1 denotes Laplace transform of x_1)

So,

$$(s+2)X_1 = \frac{1}{s} \qquad (x_1(0) = 0)$$

or, $$X_1 = \frac{1}{s(s+2)} \quad \text{....(3)}$$

Now, from Eq. (2) we have

$$y = x_1$$

Taking Laplace transform both the sides,

$$Y = X_L$$

or, $$Y = \frac{1}{s(s+2)}$$ (from eq. (3))

or, $$Y = \frac{1}{2}\left[\frac{1}{s} - \frac{1}{s+2}\right]$$

Taking inverse Laplace transform

$$y = \frac{1}{2}\left[u(t) - e^{-2t}u(t)\right]$$

$$= \frac{1}{2} - \frac{1}{2}e^{-2t} \qquad (\text{for } t > 0)$$

SOL 1.6.6 Option (A) is correct.

From the given state variable system, we have

$$A = \begin{bmatrix}-2 & 0\\ 0 & 1\end{bmatrix}$$

and $$B = \begin{bmatrix}1\\ 1\end{bmatrix};\ C = \begin{bmatrix}1 & 0\end{bmatrix}$$

Now, we obtain the controllability matrix

$$C_M = \begin{bmatrix}B & : & AB\end{bmatrix}$$

$$= \begin{bmatrix}1 & -2\\ 2 & 1\end{bmatrix}$$

and the observability matrix is obtained as

$$O_M = \begin{bmatrix}C\\ CA\end{bmatrix}$$

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$$= \begin{bmatrix} 1 & 0 \\ -2 & 0 \end{bmatrix}$$

So, we get

Rank of the controllability matrix → Rank $(C_M) = 2$

Rank of the observability matrix → Rank $(O_M) = 1$

Since, the order of state variable is $2(x_1 \text{and } x_2)$. Therefore, we have

Rank (C_M) = order of state variables

but, Rank (O_M) < order of state variables

Thus, system is controllable but not observable

SOL 1.6.7 Option (D) is correct.

General form of state equations are given as

$$\dot{x} = Ax + Bu$$

$$\dot{y} = Cx + Du$$

For the given problem

$$A = \begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$AB = \begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ a_2 \\ 0 \end{bmatrix}$$

$$A^2B = \begin{bmatrix} 0 & 0 & a_1a_2 \\ a_2a_3 & 0 & 0 \\ 0 & a_3a_1 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} a_1a_2 \\ 0 \\ 0 \end{bmatrix}$$

For controllability it is necessary that following matrix has a tank of $n = 3$.

$$U = [B : AB : A^2B] = \begin{bmatrix} 0 & 0 & a_1a_2 \\ 0 & a_2 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

So, $a_2 \neq 0$

$a_1a_2 \neq 0 \Rightarrow a_1 \neq 0$

a_3 may be zero or not.

SOL 1.6.8 Option (A) is correct.

$$Y(s) = \frac{K(s+1)}{s^3 + as^2 + 2s + 1}[R(s) - Y(s)]$$

$$Y(s)\left[1 + \frac{K(s+1)}{s^3 + as^2 + 2s + 1}\right] = \frac{K(s+1)}{s^3 + as^2 + 2s + 1}R(s)$$

$$Y(s)[s^3 + as^2 + s(2+k) + (1+k)] = K(s+1)R(s)$$

Transfer Function,

$$H(s) = \frac{Y(s)}{R(s)} = \frac{K(s+1)}{s^3 + as^2 + s(2+k) + (1+k)}$$

Routh Table :

s^3	1	$2+K$
s^2	a	$1+K$
s^1	$\frac{a(2+K)-(1+K)}{a}$	0

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For oscillation,

$$\frac{a(2+K)-(1+K)}{a}=0$$

$$a=\frac{K+1}{K+2}$$

Auxiliary equation

$$A(s)=as^2+(k+1)=0$$

$$s^2=-\frac{k+1}{a}$$

$$s^2=\frac{-k+1}{(k+1)}(k+2)=-(k+2)$$

$$s=j\sqrt{k+2}$$

$$j\omega=j\sqrt{k+2}$$

$$\omega=\sqrt{k+2}=2 \qquad \text{(Oscillation frequency)}$$

$$k=2$$

and $$a=\frac{2+1}{2+2}=\frac{3}{4}=0.75$$

SOL 1.6.9 Option (A) is correct.

$$G_C(s)=\frac{s+a}{s+b}=\frac{j\omega+a}{j\omega+b}$$

Phase lead angle, $$\phi=\tan^{-1}\left(\frac{\omega}{a}\right)-\tan^{-1}\left(\frac{\omega}{b}\right)$$

$$=\tan^{-1}\left(\frac{\frac{\omega}{a}-\frac{\omega}{b}}{1+\frac{\omega^2}{ab}}\right)$$

$$=\tan^{-1}\left(\frac{\omega(b-a)}{ab+\omega^2}\right)$$

For phase-lead compensation $\phi>0$

$$b-a>0$$

$$b>a$$

Note: For phase lead compensator zero is nearer to the origin as compared to pole, so option (C) can not be true.

SOL 1.6.10 Option (A) is correct.

$$\phi=\tan^{-1}\left(\frac{\omega}{a}\right)-\tan^{-1}\left(\frac{\omega}{b}\right)$$

$$\frac{d\phi}{d\omega}=\frac{1/a}{1+\left(\frac{\omega}{a}\right)^2}-\frac{1/b}{1+\left(\frac{\omega}{b}\right)^2}=0$$

$$\frac{1}{a}+\frac{\omega^2}{ab^2}=\frac{1}{b}+\frac{1}{b}\frac{\omega^2}{a^2}$$

$$\frac{1}{a}-\frac{1}{b}=\frac{\omega^2}{ab}\left(\frac{1}{a}-\frac{1}{b}\right)$$

$$\omega=\sqrt{ab}=\sqrt{1\times 2}=\sqrt{2}\ \text{rad/sec}$$

SOL 1.6.11 Option (A) is correct.

Gain margin is simply equal to the gain at phase cross over frequency (ω_p). Phase cross over frequency is the frequency at which phase angle is equal to -180°.

From the table we can see that $\angle G(j\omega_p)=-180^\circ$, at which gain is 0.5.

$$GM=20\log_{10}\left(\frac{1}{|G(j\omega_p)|}\right)=20\log\left(\frac{1}{0.5}\right)=6\ \text{dB}$$

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Phase Margin is equal to 180° plus the phase angle ϕ_g at the gain cross over frequency (ω_g). Gain cross over frequency is the frequency at which gain is unity. From the table it is clear that $|G(j\omega_g)| = 1$, at which phase angle is -150°

$$\phi_{PM} = 180^\circ + \angle G(j\omega_g) = 180 - 150 = 30^\circ$$

SOL 1.6.12 Option (A) is correct.

We know that steady state error is given by

$$e_{ss} = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}$$

where $R(s) \rightarrow$ input

$G(s) \rightarrow$ open loop transfer function

For unit step input

$$R(s) = \frac{1}{s}$$

So $$e_{ss} = \lim_{s\to 0} \frac{s\left(\frac{1}{s}\right)}{1+G(s)} = 0.1$$

$$1 + G(0) = 10$$

$$G(0) = 9$$

Given input $r(t) = 10[\mu(t) - \mu(t-1)]$

or $$R(s) = 10\left[\frac{1}{s} - \frac{1}{s}e^{-s}\right] = 10\left[\frac{1-e^{-s}}{s}\right]$$

So steady state error

$$e'_{ss} = \lim_{s\to 0} \frac{s \times 10\frac{(1-e^{-s})}{s}}{1+G(s)} = \frac{10(1-e^0)}{1+9} = 0$$

SOL 1.6.13 Option (B) is correct.

Transfer function having at least one zero or pole in RHS of s-plane is called non-minimum phase transfer function.

$$G(s) = \frac{s-1}{(s+2)(s+3)}$$

- In the given transfer function one zero is located at $s = 1$ (RHS), so this is a non-minimum phase system.
- Poles $-2, -3$, are in left side of the complex plane, So the system is stable

SOL 1.6.14 Option (A) is correct.

$$G(s) = \frac{K\left(s+\frac{2}{3}\right)}{s^2(s+2)}$$

Steps for plotting the root-locus

(1) Root loci starts at $s = 0, s = 0$ and $s = -2$

(2) $n > m$, therefore, number of branches of root locus $b = 3$

(3) Angle of asymptotes is given by

$$\frac{(2q+1)180^\circ}{n-m},\ q = 0, 1$$

(I) $$\frac{(2\times 0+1)180^\circ}{(3-1)} = 90^\circ$$

(II) $$\frac{(2\times 1+1)180^\circ}{(3-1)} = 270^\circ$$

(4) The two asymptotes intersect on real axis at centroid

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$$x = \frac{\sum \text{Poles} - \sum \text{Zeroes}}{n-m} = \frac{-2-\left(-\frac{2}{3}\right)}{3-1} = -\frac{2}{3}$$

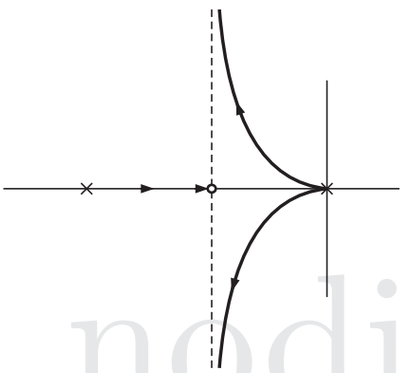
(5) Between two open-loop poles $s = 0$ and $s = -2$ there exist a break away point.

$$K = -\frac{s^2(s+2)}{\left(s+\frac{2}{3}\right)}$$

$$\frac{dK}{ds} = 0$$

$$s = 0$$

Root locus is shown in the figure



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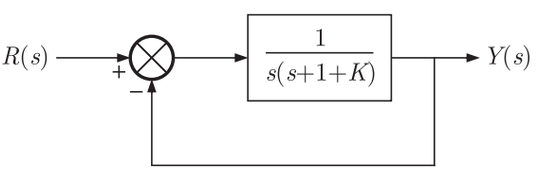
Three roots with nearly equal parts exist on the left half of s-plane.

SOL 1.6.15 Option (A) is correct.

The system may be reduced as shown below



$$\frac{Y(s)}{R(s)} = \frac{\frac{1}{s(s+1+K)}}{1+\frac{1}{s(s+1+K)}} = \frac{1}{s^2+s(1+K)+1}$$

This is a second order system transfer function, characteristic equation is

$$s^2 + s(1+K) + 1 = 0$$

Comparing with standard form

$$s^2 + 2\xi\omega_n s + \omega_n^2 = 0$$

We get $\xi = \frac{1+K}{2}$

Peak overshoot

$$M_p = e^{-\pi\xi/\sqrt{1-\xi^2}}$$

So the Peak overshoot is effected by K.

SOL 1.6.16 Option (A) is correct.

Given $G(s) = \frac{1}{s(s+1)(s+2)}$

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$$G(j\omega) = \frac{1}{j\omega(j\omega+1)(j\omega+2)}$$
$$|G(j\omega)| = \frac{1}{\omega\sqrt{\omega^2+1}\sqrt{\omega^2+4}}$$
$$\angle G(j\omega) = -90^\circ - \tan^{-1}(\omega) - \tan^{-1}(\omega/2)$$

In nyquist plot

For $\omega = 0$, $|G(j\omega)| = \infty$

$$\angle G(j\omega) = -90^\circ$$

For $\omega = \infty$, $|G(j\omega)| = 0$

$$\angle G(j\omega) = -90^\circ - 90^\circ - 90^\circ = -270^\circ$$

Intersection at real axis

$$G(j\omega) = \frac{1}{j\omega(j\omega+1)(j\omega+2)} = \frac{1}{j\omega(-\omega^2+j3\omega+2)}$$
$$= \frac{1}{-3\omega^2+j\omega(2-\omega^2)} \times \frac{-3\omega^2-j\omega(2-\omega^2)}{-3\omega^2-j\omega(2-\omega^2)}$$
$$= \frac{-3\omega^2-j\omega(2-\omega^2)}{9\omega^4+\omega^2(2-\omega^2)^2}$$
$$= \frac{-3\omega^2}{9\omega^4+\omega^2(2-\omega^2)^2} - \frac{j\omega(2-\omega^2)}{9\omega^4+\omega^2(2-\omega^2)^2}$$

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At real axis

$$\text{Im}[G(j\omega)] = 0$$

So, $\frac{\omega(2-\omega^2)}{9\omega^4+\omega^2(2-\omega^2)} = 0$

$$2-\omega^2 = 0 \Rightarrow \omega = \sqrt{2} \text{ rad/sec}$$

At $\omega = \sqrt{2}$ rad/sec, magnitude response is

$$|G(j\omega)|_{at\ \omega=\sqrt{2}} = \frac{1}{\sqrt{2}\sqrt{2+1}\sqrt{2+4}} = \frac{1}{6} < \frac{3}{4}$$

SOL 1.6.17 Option (C) is correct.

Stability :

Eigen value of the system are calculated as

$$|A-\lambda I| = 0$$
$$A-\lambda I = \begin{bmatrix}-1 & 2\\ 0 & 2\end{bmatrix} - \begin{bmatrix}\lambda & 0\\ 0 & \lambda\end{bmatrix} = \begin{bmatrix}-1-\lambda & 2\\ 0 & 2-\lambda\end{bmatrix}$$
$$|A-\lambda I| = (-1-\lambda)(2-\lambda) - 2\times 0 = 0$$
$$\Rightarrow \quad \lambda_1, \lambda_2 = -1, 2$$

Since eigen values of the system are of opposite signs, so it is unstable

Controllability :

$$A = \begin{bmatrix}-1 & 2\\ 0 & 2\end{bmatrix},\ B = \begin{bmatrix}0\\ 1\end{bmatrix}$$
$$AB = \begin{bmatrix}2\\ 2\end{bmatrix}$$
$$[B:AB] = \begin{bmatrix}0 & 2\\ 1 & 2\end{bmatrix}$$
$$[B:AB] \neq 0$$

So it is controllable.

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SOL 1.6.18 Option (C) is correct.

Given characteristic equation

$$s(s+1)(s+3)+K(s+2)=0; \qquad K>0$$

$$s(s^2+4s+3)+K(s+2)=0$$

$$s^3+4s^2+(3+K)s+2K=0$$

From Routh's tabulation method

s^3	1	$3+K$
s^2	4	$2K$
s^1	$\frac{4(3+K)-2K(1)}{4}=\frac{12+2K}{4}>0$	
s^0	$2K$	

There is no sign change in the first column of routh table, so no root is lying in right half of s-plane.

For plotting root locus, the equation can be written as

$$1+\frac{K(s+2)}{s(s+1)(s+3)}=0$$

Open loop transfer function

$$G(s)=\frac{K(s+2)}{s(s+1)(s+3)}$$

Root locus is obtained in following steps:

1. No. of poles $n=3$, at $s=0, s=-1$ and $s=-3$
2. No. of Zeroes $m=1$, at $s=-2$
3. The root locus on real axis lies between $s=0$ and $s=-1$, between $s=-3$ and $s=-2$.
4. Breakaway point lies between open loop poles of the system. Here breakaway point lies in the range $-1<\text{Re}[s]<0$.
5. Asymptotes meet on real axis at a point C, given by

$$C=\frac{\sum\text{real part of poles}-\sum\text{real parts of zeroes}}{n-m}$$

$$=\frac{(0-1-3)-(-2)}{3-1}$$

$$=-1$$

As no. of poles is 3, so two root loci branches terminates at infinity along asymptotes $\text{Re}(s)=-1$

SOL 1.6.19 Option (D) is correct.

Overall gain of the system is written as

$$G=G_1G_2\frac{1}{G_3}$$

We know that for a quantity that is product of two or more quantities total percentage error is some of the percentage error in each quantity. so error in overall gain G is

$$\Delta G=\varepsilon_1+\varepsilon_2+\frac{1}{\varepsilon_3}$$

SOL 1.6.20 Option (D) is correct.

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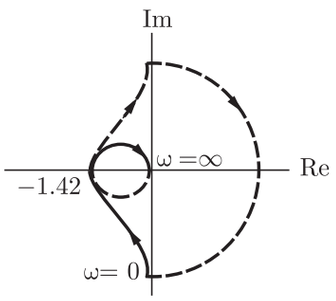
From Nyquist stability criteria, no. of closed loop poles in right half of s-plane is given as

$$Z = P - N$$

$P \rightarrow$ No. of open loop poles in right half s-plane

$N \rightarrow$ No. of encirclement of $(-1, j0)$



Here $N = -2$ ($\therefore$ encirclement is in clockwise direction)

$P = 0$ ($\therefore$ system is stable)

So, $Z = 0 - (-2)$

$Z = 2$, System is unstable with 2-poles on RH of s-plane.

SOL 1.6.21 Option (D) is correct.

Given Routh's tabulation.

s^3	2	2
s^2	4	4
s^1	0	0

So the auxiliary equation is given by,

$$4s^2 + 4 = 0$$
$$s^2 = -1$$
$$s = \pm j$$

From table we have characteristic equation as

$$2s^3 + 2s + 4s^2 + 4 = 0$$
$$s^3 + s + 2s^2 + 2 = 0$$
$$s(s^2 + 1) + 2(s^2 + 1) = 0$$
$$(s + 2)(s^2 + 1) = 0$$
$$s = -2,\ s = \pm j$$

SOL 1.6.22 Option (B) is correct.

Since initial slope of the bode plot is -40 dB/decade, so no. of poles at origin is 2.

Transfer function can be written in following steps:

1. Slope changes from -40 dB/dec. to -60 dB/dec. at $\omega_1 = 2$ rad/sec., so at ω_1 there is a pole in the transfer function.
2. Slope changes from -60 dB/dec to -40 dB/dec at $\omega_2 = 5$ rad/sec., so at this frequency there is a zero lying in the system function.
3. The slope changes from -40 dB/dec to -60 dB/dec at $\omega_3 = 25$ rad/sec, so there is a pole in the system at this frequency.

Transfer function

$$T(s) = \frac{K(s+5)}{s^2(s+2)(s+25)}$$

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Constant term can be obtained as.

$$T(j\omega)\big|_{at\ \omega=0.1} = 80$$

So,
$$80 = 20\log\frac{K(5)}{(0.1)^2 \times 50}$$

$$K = 1000$$

therefore, the transfer function is

$$T(s) = \frac{1000(s+5)}{s^2(s+2)(s+25)}$$

SOL 1.6.23 Option (D) is correct.

From the figure we can see that steady state error for given system is

$$e_{ss} = 1 - 0.75 = 0.25$$

Steady state error for unity feed back system is given by

$$e_{ss} = \lim_{s\to 0}\left[\frac{sR(s)}{1+G(s)}\right]$$

$$= \lim_{s\to 0}\left[\frac{s\left(\frac{1}{s}\right)}{1+\frac{K}{(s+1)(s+2)}}\right];\ R(s) = \frac{1}{s}\ \text{(unit step input)}$$

$$= \frac{1}{1+\frac{K}{2}} = \frac{2}{2+K}$$

So,
$$e_{ss} = \frac{2}{2+K} = 0.25$$

$$2 = 0.5 + 0.25K$$

$$K = \frac{1.5}{0.25} = 6$$

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SOL 1.6.24 Option (D) is correct.

Open loop transfer function of the figure is given by,

$$G(s) = \frac{e^{-0.1s}}{s}$$

$$G(j\omega) = \frac{e^{-j0.1\omega}}{j\omega}$$

Phase cross over frequency can be calculated as,

$$\angle G(j\omega_p) = -180^\circ$$

$$\left(-0.1\omega_p \times \frac{180}{\pi}\right) - 90^\circ = -180^\circ$$

$$0.1\omega_p \times \frac{180^\circ}{\pi} = 90^\circ$$

$$0.1\omega_p = \frac{90^\circ \times \pi}{180^\circ}$$

$$\omega_p = 15.7\ \text{rad/sec}$$

So the gain margin (dB)

$$= 20\log\left(\frac{1}{|G(j\omega_p)|}\right) = 20\log\left[\frac{1}{\left(\frac{1}{15.7}\right)}\right]$$

$$= 20\log 15.7 = 23.9\ \text{dB}$$

SOL 1.6.25 Option (C) is correct.

Given system equations

$$\frac{dx_1(t)}{dt} = -3x_1(t) + x_2(t) + 2u(t)$$

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$$\frac{dx_2(t)}{dt} = -2x_2(t) + u(t)$$

$$y(t) = x_1(t)$$

Taking Laplace transform on both sides of equations.

$$sX_1(s) = -3X_1(s) + X_2(s) + 2U(s)$$

$$(s+3)X_1(s) = X_2(s) + 2U(s) \quad ...(1)$$

Similarly $$sX_2(s) = -2X_2(s) + U(s)$$

$$(s+2)X_2(s) = U(s) \quad ...(2)$$

From equation (1) & (2)

$$(s+3)X_1(s) = \frac{U(s)}{s+2} + 2U(s)$$

$$X_1(s) = \frac{U(s)}{s+3}\left[\frac{1+2(s+2)}{s+2}\right]$$

$$= U(s)\frac{(2s+5)}{(s+2)(s+3)}$$

From output equation,

$$Y(s) = X_1(s)$$

So, $$Y(s) = U(s)\frac{(2s+5)}{(s+2)(s+3)}$$

System transfer function

$$\text{T.F} = \frac{Y(s)}{U(s)} = \frac{(2s+5)}{(s+2)(s+3)} = \frac{(2s+5)}{s^2+5s+6}$$

SOL 1.6.26 Option (B) is correct.

Given state equations in matrix form can be written as,

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}-3 & 1\\ 0 & -2\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}2\\ 1\end{bmatrix}u(t)$$

$$\frac{dX(t)}{dt} = AX(t) + Bu(t)$$

State transition matrix is given by

$$\phi(t) = \mathcal{L}^{-1}[\Phi(s)]$$

$$\Phi(s) = (sI - A)^{-1}$$

$$(sI - A) = \begin{bmatrix}s & 0\\ 0 & s\end{bmatrix} - \begin{bmatrix}-3 & 1\\ 0 & -2\end{bmatrix}$$

$$(sI - A) = \begin{bmatrix}s+3 & -1\\ 0 & s+2\end{bmatrix}$$

$$(sI - A)^{-1} = \frac{1}{(s+3)(s+2)}\begin{bmatrix}s+2 & 1\\ 0 & s+3\end{bmatrix}$$

$$\text{So } \Phi(s) = (sI - A)^{-1} = \begin{bmatrix}\frac{1}{(s+3)} & \frac{1}{(s+3)(s+2)}\\ 0 & \frac{1}{(s+2)}\end{bmatrix}$$

$$\phi(t) = \mathcal{L}^{-1}[\Phi(s)] = \begin{bmatrix}e^{-3t} & e^{-2t} - e^{-3t}\\ 0 & e^{-2t}\end{bmatrix}$$

SOL 1.6.27 Option (D) is correct.

Given differential equation for the function

$$\frac{dy(t)}{dt} + y(t) = \delta(t)$$

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Taking Laplace on both the sides we have,

$$sY(s) + Y(s) = 1$$
$$(s+1)Y(s) = 1$$
$$Y(s) = \frac{1}{s+1}$$

Taking inverse Laplace of $Y(s)$

$$y(t) = e^{-t}u(t),\ t > 0$$

SOL 1.6.28 Option (A) is correct.

Given transfer function

$$G(s) = \frac{1}{s^2+3s+2}$$

Input $r(t) = \delta(t-1)$

$$R(s) = \mathcal{L}[\delta(t-1)] = e^{-s}$$

Output is given by

$$Y(s) = R(s)G(s) = \frac{e^{-s}}{s^2+3s+2}$$

Steady state value of output

$$\lim_{t\to\infty} y(t) = \lim_{s\to 0} sY(s) = \lim_{s\to 0} \frac{se^{-s}}{s^2+3s+2} = 0$$

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SOL 1.6.29 Option (A) is correct.

For C_1 Phase is given by

$$\theta_{C_1} = \tan^{-1}(\omega) - \tan^{-1}\left(\frac{\omega}{10}\right)$$
$$= \tan^{-1}\left(\frac{\omega - \frac{\omega}{10}}{1+\frac{\omega^2}{10}}\right)$$
$$= \tan^{-1}\left(\frac{9\omega}{10+\omega^2}\right) > 0 \text{ (Phase lead)}$$

Similarly for C_2, phase is

$$\theta_{C2} = \tan^{-1}\left(\frac{\omega}{10}\right) - \tan^{-1}(\omega)$$
$$= \tan^{-1}\left(\frac{\frac{\omega}{10} - \omega}{1+\frac{\omega^2}{10}}\right)$$
$$= \tan^{-1}\left(\frac{-9\omega}{10+\omega^2}\right) < 0 \text{ (Phase lag)}$$

SOL 1.6.30 Option (C) is correct.

From the given bode plot we can analyze that:

1. Slope -40 dB/decade$\rightarrow$2 poles
2. Slope -20 dB/decade (Slope changes by $+20$ dB/decade)$\rightarrow$1 Zero
3. Slope 0 dB/decade (Slope changes by $+20$ dB/decade)$\rightarrow$1 Zero

So there are 2 poles and 2 zeroes in the transfer function.

SOL 1.6.31 Option (C) is correct.

Characteristic equation for the system

$$1 + \frac{K}{s(s+3)(s+10)} = 0$$

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$$s(s+3)(s+10)+K = 0$$
$$s^3+13s^2+30s+K = 0$$

Applying Routh's stability criteria

s^3	1	30
s^2	13	K
s^1	$\frac{(13\times 30)-K}{13}$	
s^0	K	

For stability there should be no sign change in first column

So, $390-K > 0 \Rightarrow K < 390$

$K > 0$

$0 < K < 90$

SOL 1.6.32 Option (C) is correct.

Given transfer function is

$$H(s)) = \frac{100}{s^2+20s+100}$$

Characteristic equation of the system is given by

$$s^2+20s+100 = 0$$
$$\omega_n^2 = 100 \Rightarrow \omega_n = 10 \text{ rad/sec.}$$
$$2\xi\omega_n = 20$$

or $$\xi = \frac{20}{2\times 10} = 1$$

$(\xi = 1)$ so system is critically damped.

SOL 1.6.33 Option (D) is correct.

State space equation of the system is given by,

$$\dot{X} = AX + Bu$$
$$Y = CX$$

Taking Laplace transform on both sides of the equations.

$$sX(s) = AX(s) + BU(s)$$
$$(sI-A)X(s) = BU(s)$$
$$X(s) = (sI-A)^{-1}BU(s)$$
$$\therefore\ Y(s) = CX(s)$$

So $$Y(s) = C(sI-A)^{-1}BU(s)$$

$$\text{T.F} = \frac{Y(s)}{U(s)} = C(sI-A)^{-1}B$$

$$(sI-A) = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 0 & 1 \\ 0 & -2 \end{bmatrix} = \begin{bmatrix} s & -1 \\ 0 & s+2 \end{bmatrix}$$

$$(sI-A)^{-1} = \frac{1}{s(s+2)}\begin{bmatrix} s+2 & 1 \\ 0 & s \end{bmatrix} = \begin{bmatrix} \frac{1}{s} & \frac{1}{s(s+2)} \\ 0 & \frac{1}{(s+2)} \end{bmatrix}$$

Transfer function

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$$G(s) = C[sI - A]^{-1}B = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}\frac{1}{s} & \frac{1}{s(s+2)} \\ 0 & \frac{1}{(s+2)}\end{bmatrix}\begin{bmatrix}0 \\ 1\end{bmatrix} = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}\frac{1}{s(s+2)} \\ \frac{1}{(s+2)}\end{bmatrix}$$

$$= \frac{1}{s(s+2)}$$

SOL 1.6.34 Option (A) is correct.

Steady state error is given by,

$$e_{ss} = \lim_{s \to 0}\left[\frac{sR(s)}{1 + G(s)H(s)}\right]$$

Here $R(s) = \mathcal{L}[r(t)] = \frac{1}{s}$ (Unit step input)

$$G(s) = \frac{1}{s(s+2)}$$

$H(s) = 1$ (Unity feed back)

So,
$$e_{ss} = \lim_{s \to 0}\left[\frac{s\left(\frac{1}{s}\right)}{1 + \frac{1}{s(s+2)}}\right]$$

$$= \lim_{s \to 0}\left[\frac{s(s+2)}{s(s+2)+1}\right] = 0$$

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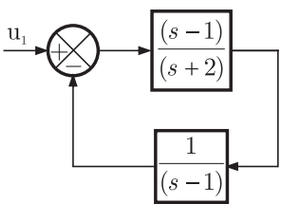
SOL 1.6.35 Option (D) is correct.

For input u_1, the system is $(u_2 = 0)$

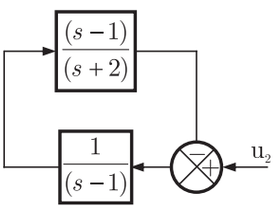


System response is

$$H_1(s) = \frac{\frac{(s-1)}{(s+2)}}{1 + \frac{(s-1)}{(s+2)}\frac{1}{(s-1)}} = \frac{(s-1)}{(s+3)}$$

Poles of the system is lying at $s = -3$ (negative s-plane) so this is stable.

For input u_2 the system is $(u_1 = 0)$



System response is

$$H_2(s) = \frac{\frac{1}{(s-1)}}{1 + \frac{1}{(s-1)}\frac{(s-1)}{(s+2)}} = \frac{(s+2)}{(s-1)(s+3)}$$

One pole of the system is lying in right half of s-plane, so the system is unstable.

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SOL 1.6.36 Option (B) is correct.

Given function is.

$$G(s) = \frac{1}{s(s+1)(s+2)}$$

$$G(j\omega) = \frac{1}{j\omega(1+j\omega)(2+j\omega)}$$

By simplifying

$$G(j\omega) = \left(\frac{1}{j\omega} \times \frac{-j\omega}{-j\omega}\right)\left(\frac{1}{1+j\omega} \times \frac{1-j\omega}{1-j\omega}\right)\left(\frac{1}{2+j\omega} \times \frac{2-j\omega}{2-j\omega}\right)$$

$$= \left(-\frac{j\omega}{\omega^2}\right)\left(\frac{1-j\omega}{1+\omega^2}\right)\left(\frac{2-j\omega}{4+\omega^2}\right) = \frac{-j\omega(2-\omega^2-j3\omega)}{\omega^2(1+\omega^2)(4+\omega^2)}$$

$$= \frac{-3\omega^2}{\omega^2(1+\omega^2)(4+\omega^2)} + \frac{j\omega(\omega^2-2)}{\omega^2(1+\omega^2)(4+\omega^2)}$$

$$G(j\omega) = x + iy$$

$$x = \text{Re}[G(j\omega)]\big|_{\omega \to 0^+} = \frac{-3}{1 \times 4} = -\frac{3}{4}$$

SOL 1.6.37 Option (D) is correct.

Let response of the un-compensated system is

$$H_{UC}(s) = \frac{900}{s(s+1)(s+9)}$$

Response of compensated system.

$$H_C(s) = \frac{900}{s(s+1)(s+9)} G_C(s)$$

Where $G_C(s) \rightarrow$ Response of compensator

Given that gain-crossover frequency of compensated system is same as phase crossover frequency of un-compensated system

So,

$$(\omega_g)_{\text{compensated}} = (\omega_p)_{\text{uncompensated}}$$

$$-180^\circ = \angle H_{UC}(j\omega_p)$$

$$-180^\circ = -90^\circ - \tan^{-1}(\omega_p) - \tan^{-1}\left(\frac{\omega_p}{9}\right)$$

$$90^\circ = \tan^{-1}\left(\frac{\omega_p + \frac{\omega_p}{9}}{1 - \frac{\omega_p^2}{9}}\right)$$

$$1 - \frac{\omega_p^2}{9} = 0$$

$$\omega_p = 3 \text{ rad/sec.}$$

So,

$$(\omega_g)_{\text{compensated}} = 3 \text{ rad/sec.}$$

At this frequency phase margin of compensated system is

$$\phi_{PM} = 180^\circ + \angle H_C(j\omega_g)$$

$$45^\circ = 180^\circ - 90^\circ - \tan^{-1}(\omega_g) - \tan^{-1}(\omega_g/9) + \angle G_C(j\omega_g)$$

$$45^\circ = 180^\circ - 90^\circ - \tan^{-1}(3) - \tan^{-1}(1/3) + \angle G_C(j\omega_g)$$

$$45^\circ = 90^\circ - \tan^{-1}\left[\frac{3+\frac{1}{3}}{1-3\left(\frac{1}{3}\right)}\right] + \angle G_C(j\omega_g)$$

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$$45^\circ = 90^\circ - 90^\circ + \angle G_C(j\omega_g)$$

$$\angle G_C(j\omega_g) = 45^\circ$$

The gain cross over frequency of compensated system is lower than un-compensated system, so we may use lag-lead compensator.

At gain cross over frequency gain of compensated system is unity so.

$$\left|H_C(j\omega_g)\right| = 1$$

$$\frac{900\left|G_C(j\omega_g)\right|}{\omega_g\sqrt{\omega_g^2+1}\sqrt{\omega_g^2+81}} = 1$$

$$\left|G_C(j\omega_g)\right| = \frac{3\sqrt{9+1}\sqrt{9+81}}{900} = \frac{3\times 30}{900} = \frac{1}{10}$$

$$\text{in dB } \left|G_C(\omega_g)\right| = 20\log\left(\frac{1}{10}\right)$$

$$= -20 \text{ dB (attenuation)}$$

SOL 1.6.38 Option (B) is correct.

Characteristic equation for the given system,

$$1 + \frac{K(s+3)}{(s+8)^2} = 0$$

$$(s+8)^2 + K(s+3) = 0$$

$$s^2 + (16+K)s + (64+3K) = 0$$

By applying Routh's criteria.

s^2	1	$64+3K$
s^1	$16+K$	0
s^0	$64+3K$	

For system to be oscillatory

$$16 + K = 0 \Rightarrow K = -16$$

$$\text{Auxiliary equation } A(s) = s^2 + (64+3K) = 0$$

$$\Rightarrow \quad s^2 + 64 + 3\times(-16) = 0$$

$$s^2 + 64 - 48 = 0$$

$$s^2 = -16 \Rightarrow j\omega = 4j$$

$$\omega = 4 \text{ rad/sec}$$

SOL 1.6.39 Option (D) is correct.

From the given block diagram we can obtain signal flow graph of the system. Transfer function from the signal flow graph is written as

$$\text{T.F} = \frac{\frac{c_0P}{s^2} + \frac{c_1P}{s}}{1 + \frac{a_1}{s} + \frac{a_0}{s^2} - \frac{Pb_0}{s^2} - \frac{Pb_1}{s}}$$

$$= \frac{(c_0 + c_1 s)P}{(s^2 + a_1 s + a_0) - P(b_0 + sb_1)}$$

$$= \frac{\frac{(c_0 + c_1 s)P}{(s^2 + a_1 s + a_0)}}{1 - \frac{P(b_0 + sb_1)}{s^2 + a_1 s + a_0}}$$

from the given reduced form transfer function is given by

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$$\text{T.F} = \frac{XYP}{1 - YPZ}$$

by comparing above two we have

$$X = (c_0 + c_1 s)$$
$$Y = \frac{1}{s^2 + a_1 s + a_0}$$
$$Z = (b_0 + s b_1)$$

SOL 1.6.40 Option (A) is correct.

For the given system Z is given by

$$Z = E(s)\frac{K_i}{s}$$

Where $E(s) \rightarrow$ steady state error of the system

Here

$$E(s) = \lim_{s \to 0} \frac{sR(s)}{1 + G(s)H(s)}$$

Input $R(s) = \frac{1}{s}$ (Unit step)

$$G(s) = \left(\frac{K_i}{s} + K_p\right)\left(\frac{\omega^2}{s^2 + 2\xi\omega s + \omega^2}\right)$$

$H(s) = 1$ (Unity feed back)

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So,

$$Z = \lim_{s \to 0}\left[\frac{s\left(\frac{1}{s}\right)}{1 + \left(\frac{K_i}{s} + K_p\right)\frac{\omega^2}{(s^2 + 2\xi\omega s + \omega^2)}}\right]\left(\frac{K_i}{s}\right)$$

$$= \lim_{s \to 0}\left[\frac{K_i}{s + (K_i + K_p s)\frac{\omega^2}{(s^2 + 2\xi\omega s + \omega^2)}}\right] = \frac{K_i}{K_i} = 1$$

SOL 1.6.41 Option (C) is correct.

System response of the given circuit can be obtained as.

$$H(s) = \frac{e_0(s)}{e_i(s)} = \frac{\left(\frac{1}{Cs}\right)}{\left(R + Ls + \frac{1}{Cs}\right)}$$

$$H(s) = \frac{1}{LCs^2 + RCs + 1} = \frac{\left(\frac{1}{LC}\right)}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

Characteristic equation is given by,

$$s^2 + \frac{R}{L}s + \frac{1}{LC} = 0$$

Here natural frequency $\omega_n = \frac{1}{\sqrt{LC}}$

$$2\xi\omega_n = \frac{R}{L}$$

Damping ratio $\xi = \frac{R}{2L}\sqrt{LC} = \frac{R}{2}\sqrt{\frac{C}{L}}$

Here $\xi = \frac{10}{2}\sqrt{\frac{1 \times 10^{-3}}{10 \times 10^{-6}}} = 0.5$ (under damped)

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So peak overshoot is given by

$$\%\ \text{peak overshoot} = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}} \times 100 = e^{\frac{-\pi \times 0.5}{\sqrt{1-(0.5)^2}}} \times 100 = 16\%$$

SOL 1.6.42 Option ( ) is correct.

SOL 1.6.43 Option (B) is correct.

In standard form for a characteristic equation give as

$s^n + a_{n-1}s^{n-1} + \ldots + a_1 s + a_0 = 0$

in its state variable representation matrix A is given as

$$A = \begin{bmatrix} 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ -a_0 & -a_1 & -a_2 & \cdots & -a_{n-1} \end{bmatrix}$$

Characteristic equation of the system is

$$4s^2 - 2s + 1 = 0$$

So, $a_2 = 4, a_1 = -2, a_0 = 1$

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -a_0 & -a_1 & -a_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & 2 & -4 \end{bmatrix}$$

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SOL 1.6.44 Option (A) is correct.

In the given options only in option (A) the nyquist plot does not enclose the unit circle $(-1, j0)$, So this is stable.

SOL 1.6.45 Option (A) is correct.

Given function is,

$$H(j\omega) = \frac{10^4(1+j\omega)}{(10+j\omega)(100+j\omega)^2}$$

Function can be rewritten as,

$$H(j\omega) = \frac{10^4(1+j\omega)}{10\left[1+j\frac{\omega}{10}\right]10^4\left[1+j\frac{\omega}{100}\right]^2}$$

$$= \frac{0.1(1+j\omega)}{\left(1+j\frac{\omega}{10}\right)\left(1+j\frac{\omega}{100}\right)^2}$$

The system is type 0, So, initial slope of the bode plot is 0 dB/decade.

Corner frequencies are

$$\omega_1 = 1 \text{ rad/sec}$$
$$\omega_2 = 10 \text{ rad/sec}$$
$$\omega_3 = 100 \text{ rad/sec}$$

As the initial slope of bode plot is 0 dB/decade and corner frequency $\omega_1 = 1$ rad/sec, the Slope after $\omega = 1$ rad/sec or $\log\omega = 0$ is$(0 + 20) = +20$ dB/dec.

After corner frequency $\omega_2 = 10$ rad/sec or $\log\omega_2 = 1$, the Slope is $(+20 - 20) = 0$ dB/dec.

Similarly after $\omega_3 = 100$ rad/sec or $\log\omega = 2$, the slope of plot is $(0 - 20 \times 2) = -40$ dB/dec.

Hence (A) is correct option.

SOL 1.6.46 Option (B) is correct.

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Given characteristic equation.

$$(s^2-4)(s+1)+K(s-1)=0$$

or
$$1+\frac{K(s-1)}{(s^2-4)(s+1)}=0$$

So, the open loop transfer function for the system.

$$G(s)=\frac{K(s-1)}{(s-2)(s+2)(s+1)},$$ no. of poles $n=3$, no of zeroes $m=1$

Steps for plotting the root-locus

(1) Root loci starts at $s=2, s=-1, s=-2$

(2) $n>m$, therefore, number of branches of root locus $b=3$

(3) Angle of asymptotes is given by

$$\frac{(2q+1)180^\circ}{n-m},\ q=0,1$$

(I) $\dfrac{(2\times 0+1)180^\circ}{(3-1)}=90^\circ$

(II) $\dfrac{(2\times 1+1)180^\circ}{(3-1)}=270^\circ$

(4) The two asymptotes intersect on real axis at

$$x=\frac{\sum \text{Poles}-\sum \text{Zeroes}}{n-m}=\frac{(-1-2+2)-(1)}{3-1}=-1$$

(5) Between two open-loop poles $s=-1$ and $s=-2$ there exist a break away point.

$$K=-\frac{(s^2-4)(s+1)}{(s-1)}$$

$$\frac{dK}{ds}=0$$

$$s=-1.5$$

SOL 1.6.47 Option (C) is correct.

Closed loop transfer function of the given system is,

$$T(s)=\frac{s^2+4}{(s+1)(s+4)}$$

$$T(j\omega)=\frac{(j\omega)^2+4}{(j\omega+1)(j\omega+4)}$$

If system output is zero

$$|T(j\omega)|=\frac{|4-\omega^2|}{|(j\omega+1)(j\omega+4)|}=0$$

$$4-\omega^2=0$$

$$\omega^2=4$$

$$\Rightarrow \omega=2 \text{ rad/sec}$$

SOL 1.6.48 Option (A) is correct.

From the given plot we can see that centroid C (point of intersection) where asymptotes intersect on real axis) is 0

So for option (a)

$$G(s)=\frac{K}{s^3}$$

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$$\text{Centroid} = \frac{\sum \text{Poles} - \sum \text{Zeros}}{n-m} = \frac{0-0}{3-0} = 0$$

SOL 1.6.49 Option (A) is correct.

Open loop transfer function is.

$$G(s) = \frac{(s+1)}{s^2}$$

$$G(j\omega) = \frac{j\omega + 1}{-\omega^2}$$

Phase crossover frequency can be calculated as.

$$\angle G(j\omega_p) = -180^\circ$$

$$\tan^{-1}(\omega_p) = -180^\circ$$

$$\omega_p = 0$$

Gain margin of the system is.

$$\text{G.M} = \frac{1}{|G(j\omega_p)|} = \frac{1}{\frac{\sqrt{\omega_p^2+1}}{\omega_p^2}} = \frac{\omega_p^2}{\sqrt{\omega_p^2+1}} = 0$$

SOL 1.6.50 Option (C) is correct.

Characteristic equation for the given system

$$1 + G(s)H(s) = 0$$

$$1 + K\frac{(1-s)}{(1+s)} = 0$$

$$(1+s) + K(1-s) = 0$$

$$s(1-K) + (1+K) = 0$$

For the system to be stable, coefficient of characteristic equation should be of same sign.

$$1 - K > 0,\ K + 1 > 0$$

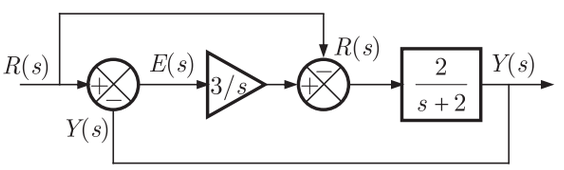
$$K < 1,\ K > -1$$

$$-1 < K < 1$$

$$|K| < 1$$

SOL 1.6.51 Option (C) is correct.

In the given block diagram



Steady state error is given as

$$e_{ss} = \lim_{s \to 0} sE(s)$$

$$E(s) = R(s) - Y(s)$$

$Y(s)$ can be written as

$$Y(s) = \left[\{R(s) - Y(s)\}\frac{3}{s} - R(s)\right]\frac{2}{s+2}$$

$$= R(s)\left[\frac{6}{s(s+2)} - \frac{2}{s+2}\right] - Y(s)\left[\frac{6}{s(s+2)}\right]$$

$$Y(s)\left[1 + \frac{6}{s(s+2)}\right] = R(s)\left[\frac{6-2s}{s(s+2)}\right]$$

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$$Y(s) = R(s)\frac{(6-2s)}{(s^2+2s+6)}$$

So, $$E(s) = R(s) - \frac{(6-2s)}{(s^2+2s+6)}R(s)$$

$$= R(s)\left[\frac{s^2+4s}{s^2+2s+6}\right]$$

For unit step input $R(s) = \frac{1}{s}$

Steady state error $e_{ss} = \lim_{s\to 0} sE(s)$

$$e_{ss} = \lim_{s\to 0}\left[s\frac{1}{s}\frac{(s^2+4s)}{(s^2+2s+6)}\right] = 0$$

SOL 1.6.52 Option (B) is correct.

When it passes through negative real axis at that point phase angle is -180°So

$$\angle G(j\omega)H(j\omega) = -180^\circ$$

$$-0.25j\omega - \frac{\pi}{2} = -\pi$$

$$-0.25j\omega = -\frac{\pi}{2}$$

$$j0.25\omega = \frac{\pi}{2}$$

$$j\,\omega = \frac{\pi}{2\times 0.25}$$

$$s = j\omega = 2\pi$$

Put $s = 2\pi$ in given open loop transfer function we get

$$G(s)H(s)\big|_{s=2\pi} = \frac{\pi e^{-0.25\times 2\pi}}{2\pi} = -0.5$$

So it passes through $(-0.5, j0)$

SOL 1.6.53 Option (C) is correct.

Open loop transfer function of the system is given by.

$$G(s)H(s) = (K+0.366s)\left[\frac{1}{s(s+1)}\right]$$

$$G(j\omega)H(j\omega) = \frac{K+j0.366\omega}{j\omega(j\omega+1)}$$

Phase margin of the system is given as

$$\phi_{PM} = 60^\circ = 180^\circ + \angle G(j\omega_g)H(j\omega_g)$$

Where $\omega_g \rightarrow$ gain cross over frequency $= 1$ rad/sec

So, $$60^\circ = 180^\circ + \tan^{-1}\left(\frac{0.366\omega_g}{K}\right) - 90^\circ - \tan^{-1}(\omega_g)$$

$$= 90^\circ + \tan^{-1}\left(\frac{0.366}{K}\right) - \tan^{-1}(1)$$

$$= 90^\circ - 45^\circ + \tan^{-1}\left(\frac{0.366}{K}\right)$$

$$15^\circ = \tan^{-1}\left(\frac{0.366}{K}\right)$$

$$\frac{0.366}{K} = \tan 15^\circ$$

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$$K = \frac{0.366}{0.267} = 1.366$$

SOL 1.6.54 Option (A) is correct.

Given state equation.

$$\dot{X}(t) = \begin{bmatrix} 0 & 1 \\ 0 & -3 \end{bmatrix} X(t) + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(t)$$

Here

$$A = \begin{bmatrix} 0 & 1 \\ 0 & -3 \end{bmatrix}, B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

State transition matrix is given by,

$$\phi(t) = \mathcal{L}^{-1}[(sI - A)^{-1}]$$

$$[sI - A] = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 0 & 1 \\ 0 & -3 \end{bmatrix} = \begin{bmatrix} s & -1 \\ 0 & s+3 \end{bmatrix}$$

$$[sI - A]^{-1} = \frac{1}{s(s+3)} \begin{bmatrix} s+3 & 1 \\ 0 & s \end{bmatrix} = \begin{bmatrix} \frac{1}{s} & \frac{1}{s(s+3)} \\ 0 & \frac{1}{(s+3)} \end{bmatrix}$$

$$\phi(t) = \mathcal{L}^{-1}[(sI - A)^{-1}]$$

$$= \begin{bmatrix} 1 & \frac{1}{3}(1 - e^{-3t}) \\ 0 & e^{-3t} \end{bmatrix}$$

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SOL 1.6.55 Option (C) is correct.

State transition equation is given by

$$X(s) = \Phi(s) X(0) + \Phi(s) B U(s)$$

Here $\Phi(s) \rightarrow$ state transition matrix

$$\Phi(s) = \begin{bmatrix} \frac{1}{s} & \frac{1}{s(s+3)} \\ 0 & \frac{1}{(s+3)} \end{bmatrix}$$

$X(0) \rightarrow$ initial condition

$$X(0) = \begin{bmatrix} -1 \\ 3 \end{bmatrix}$$

$$\text{B} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

So

$$X(s) = \begin{bmatrix} \frac{1}{s} & \frac{1}{s(s+3)} \\ 0 & \frac{1}{(s+3)} \end{bmatrix} \begin{bmatrix} -1 \\ 3 \end{bmatrix} + \begin{bmatrix} \frac{1}{s} & \frac{1}{(s+3)s} \\ 0 & \frac{1}{s+3} \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} \frac{1}{s}$$

$$= \begin{bmatrix} -\frac{1}{s} + \frac{3}{s(s+3)} \\ 0 + \frac{3}{s+3} \end{bmatrix} + \begin{bmatrix} \frac{1}{s} \\ 0 \end{bmatrix} \frac{1}{s} = \begin{bmatrix} -\frac{1}{s+3} \\ \frac{3}{s+3} \end{bmatrix} + \begin{bmatrix} \frac{1}{s^2} \\ 0 \end{bmatrix}$$

$$X(s) = \begin{bmatrix} \frac{1}{s^2} - \frac{1}{s+3} \\ \frac{3}{s+3} \end{bmatrix}$$

Taking inverse Laplace transform, we get state transition equation as,

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$$X(t) = \begin{bmatrix} t - e^{-3t} \\ 3e^{-3t} \end{bmatrix}$$

SOL 1.6.56 Option () is correct

Phase margin of a system is the amount of additional phase lag required to bring the system to the point of instability or $(-1, j0)$

So here phase margin $= 0^\circ$

SOL 1.6.57 Option (D) is correct.

Given transfer function is

$$F(s) = \frac{5}{s(s^2 + 3s + 2)}$$

$$F(s) = \frac{5}{s(s+1)(s+2)}$$

By partial fraction, we get

$$F(s) = \frac{5}{2s} - \frac{5}{s+1} + \frac{5}{2(s+2)}$$

Taking inverse Laplace of $F(s)$ we have

$$f(t) = \frac{5}{2}u(t) - 5e^{-t} + \frac{5}{2}e^{-2t}$$

So, the initial value of $f(t)$ is given by

$$\lim_{t \to 0} f(t) = \frac{5}{2} - 5 + \frac{5}{2}(1) = 0$$

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SOL 1.6.58 Option (C) is correct.

In A.C techo-meter output voltage is directly proportional to differentiation of rotor displacement.

$$e(t) \propto \frac{d}{dt}[\theta(t)]$$

$$e(t) = K_t \frac{d\theta(t)}{dt}$$

Taking Laplace tranformation on both sides of above equation

$$E(s) = K_t s\theta(s)$$

So transfer function

$$\text{T.F} = \frac{E(s)}{\theta(s)} = (K_t)s$$

SOL 1.6.59 Option (B) is correct.

Given characteristic equation,

$$s^3 - 4s^2 + s + 6 = 0$$

Applying Routh's method,

s^3	1	1
s^2	-4	6
s^1	$\frac{-4-6}{-4} = 2.5$	0
s^0	6	

There are two sign changes in the first column, so no. of right half poles is 2.

No. of roots in left half of s-plane $= (3 - 2) = 1$

SOL 1.6.60 Option (B) is correct.

Block diagram of the system is given as.

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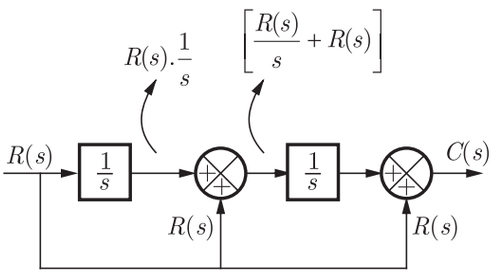

From the figure we can see that

$$C(s) = \left[R(s)\frac{1}{s} + R(s)\right]\frac{1}{s} + R(s)$$

$$C(s) = R(s)\left[\frac{1}{s^2} + \frac{1}{s} + 1\right]$$

$$\frac{C(s)}{R(s)} = \frac{1 + s + s^2}{s^2}$$

SOL 1.6.61 Option (A) is correct.

Characteristic equation is given by,

$$|sI - A| = 0$$

$$(sI - A) = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 0 & 2 \\ 2 & 0 \end{bmatrix} = \begin{bmatrix} s & -2 \\ -2 & s \end{bmatrix} = s^2 - 4 = 0$$

$$s_1, s_2 = \pm 2$$

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SOL 1.6.62 Option (D) is correct.

For the given system, characteristic equation can be written as,

$$1 + \frac{K}{s(s+2)}(1 + sP) = 0$$

$$s(s+2) + K(1 + sP) = 0$$

$$s^2 + s(2 + KP) + K = 0$$

From the equation.

$$\omega_n = \sqrt{K} = 5 \text{ rad/sec (given)}$$

So, $K = 25$

and $2\xi\omega_n = 2 + KP$

$$2 \times 0.7 \times 5 = 2 + 25P$$

or $P = 0.2$

so $K = 25$, $P = 0.2$

SOL 1.6.63 Option (D) is correct.

Unit - impulse response of the system is given as,

$$c(t) = 12.5e^{-6t}\sin 8t,\ t \geq 0$$

So transfer function of the system.

$$H(s) = \mathcal{L}[c(t)] = \frac{12.5 \times 8}{(s+6)^2 + (8)^2}$$

$$H(s) = \frac{100}{s^2 + 12s + 100}$$

Steady state value of output for unit step input,

$$\lim_{t \to \infty} y(t) = \lim_{s \to 0} sY(s) = \lim_{s \to 0} sH(s)R(s)$$

$$= \lim_{s \to 0} s\left[\frac{100}{s^2 + 12s + 100}\right]\frac{1}{s} = 1.0$$

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SOL 1.6.64 Option (A) is correct.

System response is.

$$H(s) = \frac{s}{s+1}$$

$$H(j\omega) = \frac{j\omega}{j\omega+1}$$

Amplitude response

$$|H(j\omega)| = \frac{\omega}{\sqrt{\omega+1}}$$

Given input frequency $\omega = 1$ rad/sec.

So $$|H(j\omega)|_{\omega=1\,\text{rad/sec}} = \frac{1}{\sqrt{1+1}} = \frac{1}{\sqrt{2}}$$

Phase response

$$\theta_h(\omega) = 90^\circ - \tan^{-1}(\omega)$$

$$\theta_h(\omega)\big|_{\omega=1} = 90^\circ - \tan^{-1}(1) = 45^\circ$$

So the output of the system is

$$y(t) = |H(j\omega)|x(t-\theta_h) = \frac{1}{\sqrt{2}}\sin(t-45^\circ)$$

SOL 1.6.65 Option (C) is correct.

Given open loop transfer function

$$G(j\omega) = \frac{ja\omega+1}{(j\omega)^2}$$

Gain crossover frequency (ω_g) for the system.

$$|G(j\omega_g)| = 1$$

$$\frac{\sqrt{a^2\omega_g^2+1}}{-\omega_g^2} = 1$$

$$a^2\omega_g^2 + 1 = \omega_g^4$$

$$\omega_g^4 - a^2\omega_g^2 - 1 = 0 \quad \ldots(1)$$

Phase margin of the system is

$$\phi_{PM} = 45^\circ = 180^\circ + \angle G(j\omega_g)$$

$$45^\circ = 180^\circ + \tan^{-1}(\omega_g a) - 180^\circ$$

$$\tan^{-1}(\omega_g a) = 45^\circ$$

$$\omega_g a = 1 \quad (2)$$

From equation (1) and (2)

$$\frac{1}{a^4} - 1 - 1 = 0$$

$$a^4 = \frac{1}{2} \Rightarrow a = 0.841$$

SOL 1.6.66 Option (C) is correct.

Given system equation is.

$$\frac{d^2x}{dt^2} + 6\frac{dx}{dt} + 5x = 12(1 - e^{-2t})$$

Taking Laplace transform on both side.

$$s^2X(s) + 6sX(s) + 5X(s) = 12\left[\frac{1}{s} - \frac{1}{s+2}\right]$$

$$(s^2 + 6s + 5)X(s) = 12\left[\frac{2}{s(s+2)}\right]$$

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System transfer function is

$$X(s) = \frac{24}{s(s+2)(s+5)(s+1)}$$

Response of the system as $t \to \infty$ is given by

$$\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s) \quad \text{(final value theorem)}$$

$$= \lim_{s\to 0} s\left[\frac{24}{s(s+2)(s+5)(s+1)}\right]$$

$$= \frac{24}{2\times 5} = 2.4$$

SOL 1.6.67 Option (A) is correct.

Transfer function of lead compensator is given by.

$$H(s) = \frac{K\left(1+\frac{s}{a}\right)}{\left(1+\frac{s}{b}\right)}$$

$$H(j\omega) = K\left[\frac{1+j\left(\frac{\omega}{a}\right)}{1+j\left(\frac{\omega}{b}\right)}\right]$$

So, phase response of the compensator is.

$$\theta_h(\omega) = \tan^{-1}\left(\frac{\omega}{a}\right) - \tan^{-1}\left(\frac{\omega}{b}\right)$$

$$= \tan^{-1}\left(\frac{\frac{\omega}{a}-\frac{\omega}{b}}{1+\frac{\omega^2}{ab}}\right) = \tan^{-1}\left[\frac{\omega(b-a)}{ab+\omega^2}\right]$$

θ_h should be positive for phase lead compensation

So, $$\theta_h(\omega) = \tan^{-1}\left[\frac{\omega(b-a)}{ab+\omega^2}\right] > 0$$

$$b > a$$

SOL 1.6.68 Option (A) is correct.

Since there is no external input, so state is given by

$$X(t) = \phi(t)\,X(0)$$

$\phi(t)$ →state transition matrix

$X[0]$ →initial condition

So $$x(t) = \begin{bmatrix} e^{-2t} & 0 \\ 0 & e^{-t} \end{bmatrix}\begin{bmatrix} 2 \\ 3 \end{bmatrix}$$

$$x(t) = \begin{bmatrix} 2e^{-2t} \\ 3e^{-t} \end{bmatrix}$$

At $t = 1$, state of the system

$$x(t)\big|_{t=1} = \begin{bmatrix} 2e^{-2} \\ 2e^{-1} \end{bmatrix} = \begin{bmatrix} 0.271 \\ 1.100 \end{bmatrix}$$

SOL 1.6.69 Option (B) is correct.

Given equation

$$\frac{d^2x}{dt^2} + \frac{1}{2}\frac{dx}{dt} + \frac{1}{18}x = 10 + 5e^{-4t} + 2e^{-5t}$$

Taking Laplace on both sides we have

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$$s^2X(s)+\frac{1}{2}sX(s)+\frac{1}{18}X(s)=\frac{10}{s}+\frac{5}{s+4}+\frac{2}{s+5}$$

$$\left(s^2+\frac{1}{2}s+\frac{1}{18}\right)X(s)=\frac{10(s+4)(s+5)+5s(s+5)+2s(s+4)}{s(s+4)(s+5)}$$

System response is,

$$X(s)=\frac{10(s+4)(s+5)+5s(s+5)+2s(s+4)}{s(s+4)(s+5)\left(s^2+\frac{1}{2}s+\frac{1}{18}\right)}$$

$$=\frac{10(s+4)(s+5)+5s(s+5)+2s(s+4)}{s(s+4)(s+5)\left(s+\frac{1}{3}\right)\left(s+\frac{1}{6}\right)}$$

We know that for a system having many poles, nearness of the poles towards imaginary axis in s-plane dominates the nature of time response. So here time constant given by two poles which are nearest to imaginary axis.

Poles nearest to imaginary axis

$$s_1=-\frac{1}{3},\ s_2=-\frac{1}{6}$$

So, time constants $\begin{cases}\tau_1=3\text{ sec}\\ \tau_2=6\text{ sec}\end{cases}$

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SOL 1.6.70 Option (A) is correct.

Steady state error for a system is given by

$$e_{ss}=\lim_{s\to 0}\frac{sR(s)}{1+G(s)H(s)}$$

Where input $R(s)=\frac{1}{s}$ (unit step)

$$G(s)=\left(\frac{3}{s+15}\right)\left(\frac{15}{s+1}\right)$$

$$H(s)=1 \quad \text{(unity feedback)}$$

So $$e_{ss}=\lim_{s\to 0}\frac{s\left(\frac{1}{s}\right)}{1+\frac{45}{(s+15)(s+1)}}=\frac{15}{15+45}=\frac{15}{60}$$

$$\%e_{ss}=\frac{15}{60}\times 100=25\%$$

SOL 1.6.71 Option (C) is correct.

Characteristic equation is given by

$$1+G(s)H(s)=0$$

Here $$H(s)=1 \quad \text{(unity feedback)}$$

$$G(s)=\left(\frac{3}{s+15}\right)\left(\frac{15}{s+1}\right)$$

So, $$1+\left(\frac{3}{s+15}\right)\left(\frac{15}{s+1}\right)=0$$

$$(s+15)(s+1)+45=0$$

$$s^2+16s+60=0$$

$$(s+6)(s+10)=0$$

$$s=-6,\ -10$$

SOL 1.6.72 Option (A) is correct.

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Given equation can be written as,

$$\frac{d^2\omega}{dt^2} = -\frac{\beta}{J}\frac{d\omega}{dt} - \frac{K^2}{LJ}\omega + \frac{K}{LJ}V_a$$

Here state variables are defined as,

$$\frac{d\omega}{dt} = x_1$$

$$\omega = x_2$$

So state equation is

$$\dot{x_1} = -\frac{B}{J}x_1 - \frac{K^2}{LJ}x_2 + \frac{K}{LJ}V_a$$

$$\dot{x_2} = \frac{d\omega}{dt} = x_1$$

In matrix form

$$\begin{bmatrix}\dot{x_1}\\ \dot{x_2}\end{bmatrix} = \begin{bmatrix}-B/J & -K^2/LJ\\ 1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}K/LJ\\ 0\end{bmatrix}V_a$$

$$\begin{bmatrix}\frac{d^2\omega}{dt^2}\\ \frac{d\omega}{dt}\end{bmatrix} = P\begin{bmatrix}d\omega\\ dt\end{bmatrix} + QV_a$$

So matrix P is

$$\begin{bmatrix}-B/J & -K^2/LJ\\ 1 & 0\end{bmatrix}$$

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SOL 1.6.73 Option (C) is correct.

Characteristic equation of the system is given by

$$1 + GH = 0$$

$$1 + \frac{K}{s(s+2)(s+4)} = 0$$

$$s(s+2)(s+4) + K = 0$$

$$s^3 + 6s^2 + 8s + K = 0$$

Applying routh's criteria for stability

s^3	1	8
s^2	6	K
s^1	$\frac{K-48}{6}$	
s^0	K	

System becomes unstable if $\frac{K-48}{6} = 0 \Rightarrow K = 48$

SOL 1.6.74 Option (A) is correct.

The maximum error between the exact and asymptotic plot occurs at corner frequency.

Here exact gain(dB) at $\omega = 0.5a$ is given by

$$\text{gain(dB)}\big|_{\omega=0.5a} = 20\log K - 20\log\sqrt{1+\frac{\omega^2}{a^2}}$$

$$= 20\log K - 20\log\left[1+\frac{(0.5a)^2}{a^2}\right]^{1/2}$$

$$= 20\log K - 0.96$$

Gain(dB) calculated from asymptotic plot at $\omega = 0.5a$ is

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$$= 20\log K$$

Error in gain (dB) $= 20\log K - (20\log K - 0.96)\,\text{dB} = 0.96\ \text{dB}$

Similarly exact phase angle at $\omega = 0.5a$ is.

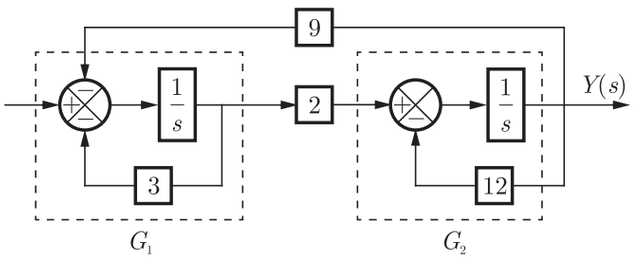
$$\theta_h(\omega)\big|_{\omega=0.5a} = -\tan^{-1}\left(\frac{\omega}{a}\right) = -\tan^{-1}\left(\frac{0.5a}{a}\right) = -26.56^\circ$$

Phase angle calculated from asymptotic plot at $(\omega = 0.5a)$ is -22.5°

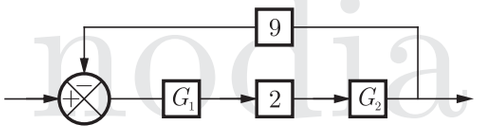
Error in phase angle $= -22.5 - (-26.56^\circ) = 4.9^\circ$

SOL 1.6.75 Option (B) is correct.

Given block diagram



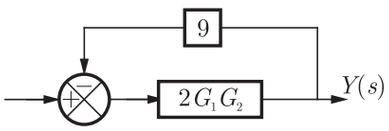
Given block diagram can be reduced as



Where $$G_1 = \frac{\left(\frac{1}{s}\right)}{1+\left(\frac{1}{s}\right)^3} = \frac{1}{s+3}$$

$$G_2 = \frac{\left(\frac{1}{s}\right)}{1+\left(\frac{1}{s}\right)12} = \frac{1}{s+12}$$

Further reducing the block diagram.



$$Y(s) = \frac{2G_1G_2}{1+(2G_1G_2)9}$$

$$= \frac{(2)\left(\frac{1}{s+3}\right)\left(\frac{1}{s+12}\right)}{1+(2)\left(\frac{1}{s+3}\right)\left(\frac{1}{s+12}\right)(9)}$$

$$= \frac{2}{(s+3)(s+12)+18} = \frac{2}{s^2+15s+54}$$

$$= \frac{2}{(s+9)(s+6)} = \frac{1}{27\left(1+\frac{s}{9}\right)\left(1+\frac{s}{6}\right)}$$

SOL 1.6.76 Option (C) is correct.

Given state equation is,

$$\dot{X} = AX$$

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Taking Laplace transform on both sides of the equation,

$$sX(s) - X(0) = AX(s)$$
$$(sI - A)X(s) = X(0)$$
$$X(s) = (sI - A)^{-1}X(0) = \Phi(s)X(0)$$

Where $\phi(t) = \mathcal{L}^{-1}[\Phi(s)] = \mathcal{L}^{-1}[(sI - A)^{-1}]$ is defined as state transition matrix

SOL 1.6.77 Option (B) is correct.

State equation of the system is given as,

$$\dot{X} = \begin{bmatrix} 2 & 3 \\ 0 & 5 \end{bmatrix} X + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$$

Here $$A = \begin{bmatrix} 2 & 3 \\ 0 & 5 \end{bmatrix},\ B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

Check for controllability:

$$AB = \begin{bmatrix} 2 & 3 \\ 0 & 5 \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 2 \\ 0 \end{bmatrix}$$
$$U = [B : AB] = \begin{bmatrix} 1 & 2 \\ 0 & 0 \end{bmatrix}$$
$$|U| = (1 \times 0 - 2 \times 0) = 0$$

Matrix U is singular, so the system is uncontrollable.

Check for Stability:

Characteristic equation of the system is obtained as,

$$|sI - A| = 0$$
$$(sI - A) = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 2 & 3 \\ 0 & 5 \end{bmatrix}$$
$$= \begin{bmatrix} s-2 & -3 \\ 0 & s-5 \end{bmatrix}$$
$$|sI - A| = (s-2)(s-5) = 0$$
$$s = 2,\ s = 5$$

There are two R.H.S Poles in the system so it is unstable.

SOL 1.6.78 Option (B) is correct.

Given open loop transfer function,

$$G(s) = \frac{K}{s^2}, \quad \begin{matrix} \text{no of poles} = 2 \\ \text{no of zeroes} = 0 \end{matrix}$$

For plotting root locus:

(1) Poles lie at $s_1, s_2 = 0$

(2) So the root loci starts ($K = 0$) from s = 0 and s = 0

(3) As there is no open-loop zero, root loci terminates ($K = \infty$) at infinity.

(4) Angle of asymptotes is given by

$$\frac{(2q+1)180^\circ}{n-m},\ q = 0, 1$$

So the two asymptotes are at an angle of

(i) $\dfrac{(2 \times 0 + 1)180^\circ}{2} = 90^\circ$

(ii) $\dfrac{(2 \times 1 + 1)180^\circ}{2} = 270^\circ$

(5) The asymptotes intersect on real axis at a point given by

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$$x = \frac{\sum \text{Poles} - \sum \text{zeros}}{n-m} = \frac{0-0}{2} = 0$$

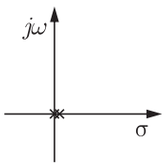
(6) Break away points

$$1 + \frac{K}{s^2} = 0$$

$$K = -s^2$$

$$\frac{dK}{ds} = -2s = 0 \Rightarrow s = 0$$

So the root locus plot is.



SOL 1.6.79 Option (A) is correct.

System is described as.

$$\frac{d^2y}{dt^2} + \frac{dy}{dt} = \frac{du}{dt} + 2u$$

Taking Laplace transform on both sides.

$$s^2 Y(s) + sY(s) = sU(s) + 2U(s)$$

$$(s^2 + s)\, Y(s) = (s+2)\, U(s)$$

So, the transfer function is

$$\text{T.F} = \frac{Y(s)}{U(s)} = \frac{(s+2)}{(s^2+s)}$$

SOL 1.6.80 Option (A) is correct.

Here, we have

$$A = \begin{bmatrix} 2 & 0 \\ 0 & 4 \end{bmatrix},\ B = \begin{bmatrix} 1 \\ 1 \end{bmatrix},\ C = [4,\ \ 0]$$

We know that transfer function of the system is given by.

$$G(s) = \frac{Y(s)}{U(s)} = C(sI - A)^{-1}B$$

$$[sI - A] = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 2 & 0 \\ 0 & 4 \end{bmatrix} = \begin{bmatrix} s-2 & 0 \\ 0 & s-4 \end{bmatrix}$$

$$(sI - A)^{-1} = \frac{1}{(s-2)(s-4)} \begin{bmatrix} (s-4) & 0 \\ 0 & (s-2) \end{bmatrix}$$

$$= \begin{bmatrix} \frac{1}{(s-2)} & 0 \\ 0 & \frac{1}{(s-4)} \end{bmatrix}$$

So,
$$\frac{Y(s)}{U(s)} = [4 \quad 0] \begin{bmatrix} \frac{1}{(s-2)} & 0 \\ 0 & \frac{1}{(s-4)} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = [4 \quad 0] \begin{bmatrix} \frac{1}{(s-2)} \\ \frac{1}{(s-4)} \end{bmatrix}$$

$$\frac{Y(s)}{U(s)} = \frac{4}{(s-2)}$$

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Here input is unit impulse so $U(s) = 1$ and output

$$Y(s) = \frac{4}{(s-2)}$$

Taking inverse Laplace transfer we get output

$$y(t) = 4e^{2t}$$

SOL 1.6.81 Option (D) is correct.

Given state equation

$$\dot{X} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} X$$

Here $$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Eigen value can be obtained as

$$|A - \lambda I| = 0$$

$$(A - \lambda I) = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} \lambda & 0 & 0 & 0 \\ 0 & \lambda & 0 & 0 \\ 0 & 0 & \lambda & 0 \\ 0 & 0 & 0 & \lambda \end{bmatrix}$$

$$= \begin{bmatrix} -\lambda & 1 & 0 & 0 \\ 0 & -\lambda & 1 & 0 \\ 0 & 0 & -\lambda & 1 \\ 0 & 0 & 0 & 1-\lambda \end{bmatrix}$$

$$|A - \lambda I| = \lambda^3(1-\lambda) = 0$$

or $\lambda_1, \lambda_2, \lambda_3 = 0,\ \lambda_4 = 1$

SOL 1.6.82 Option (A) is correct.

Input-output relationship is given as

$$\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 10y = 5\frac{du}{dt} - 3u$$

Taking Laplace transform on both sides with zero initial condition.

$$s^2 Y(s) + 2sY(s) + 10Y(s) = 5sU(s) - 3U(s)$$

$$(s^2 + 2s + 10)\, Y(s) = (5s - 3)\, U(s)$$

Output $$Y(s) = \frac{(5s-3)}{(s^2+2s+10)} U(s)$$

With no input and with given initial conditions, output is obtained as

$$\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 10y = 0$$

Taking Laplace transform (with initial conditions)

$$[s^2 Y(s) - sy(0) - y'(0)] + 2[sY(s) - y(0)] + 10Y(s) = 0$$

Given that $y'(0) = -4,\ y(0) = 1$

$$[s^2 Y(s) - s - (-4)] + 2(s-1) + 10Y(s) = 0$$

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$$Y(s)[s^2+2s+10] = (s-2)$$

$$Y(s) = \frac{(s-2)}{(s^2+2s+10)}$$

Output in both cases are same so

$$\frac{(5s-3)}{(s^2+2s+10)}U(s) = \frac{(s-2)}{(s^2+2s+10)}$$

$$U(s) = \frac{(s-2)}{(5s-3)} = \frac{1}{5}\frac{(5s-10)}{(5s-3)}$$

$$= \frac{1}{5}\left[\frac{(5s-3)}{5s-3} - \frac{7}{(5s-3)}\right]$$

$$U(s) = \frac{1}{5}\left[1 - \frac{7}{(5s-3)}\right]$$

Taking inverse Laplace transform, input is

$$u(t) = \frac{1}{5}\left[\delta(t) - \frac{5}{5}e^{3/5t}u(t)\right]$$

$$= \frac{1}{5}\delta(t) - \frac{7}{25}e^{3/5t}u(t)$$

SOL 1.6.83 Option (C) is correct.

$$\frac{d^2y}{dt^2} + \frac{dy}{dt} - 2y = u(t)e^{-t} \quad \ldots(1)$$

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State variable representation is given as

$$\dot{X} = AX + Bu$$

Or

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = A\begin{bmatrix}x_1\\ x_2\end{bmatrix} + Bu$$

Here $x_1 = y$, $x_2 = \left(\frac{dy}{dt} - y\right)e^t$

$$\frac{dx_1}{dt} = \frac{dy}{dt} = x_2e^{-t} + y = x_2e^{-t} + x_1$$

or

$$\frac{dx_1}{dt} = x_1 + x_2e^{-t} + (0)u(t) \quad \ldots(2)$$

Similarly

$$\frac{dx_2}{dt} = \frac{d^2y}{dt^2}e^t + \frac{dy}{dt}e^t - e^t\frac{dy}{dt} - ye^t$$

Put $\frac{d^2y}{dt^2}$ from equation (1)

So,

$$\frac{dx_2}{dt} = \left[u(t)e^{-t} - \frac{dy}{dt} + 2y\right]e^t - ye^t$$

$$= u(t) - \frac{dy}{dt}e^t + 2ye^t - ye^t$$

$$= u(t) - [x_2e^{-t} + y]e^t + ye^t$$

$$= u(t) - x_2$$

$$\frac{dx_2}{dt} = 0 - x_2 + u(t) \quad \ldots(3)$$

From equation (2) and (3) state variable representation is

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}1 & e^{-t}\\ 0 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}0\\ 1\end{bmatrix}u(t)$$

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SOL 1.6.84 Option (B) is correct.

Characteristic equation of the system

$$1+G(s)=0$$

$$1+\frac{2(s+\alpha)}{s(s+2)(s+10)}=0$$

$$s(s+2)(s+10)+2(s+\alpha)=0$$

$$s^3+12s^2+20s+2s+2\alpha=0$$

$$s^3+12s^2+22s+2\alpha=0$$

$$1+\frac{2\alpha}{s^3+12s^2+22s}=0$$

$$\text{No of poles } n=3$$

$$\text{No. of zeros } m=0$$

Angle of asymptotes

$$\phi_A=\frac{(2q+1)180^\circ}{n-m},\ q=0,1,2$$

$$\phi_A=\frac{(2q+1)180^\circ}{3}=(2q+1)60^\circ$$

$$\phi_A=60^\circ,180^\circ,300^\circ$$

SOL 1.6.85 Option (A) is correct.

Asymptotes intercepts at real axis at the point

$$C=\frac{\sum\text{real Parts of Poles}-\sum\text{real Parts of zeros}}{n-m}$$

Poles at $s_1=0$

$s_2=-2$

$s_3=-10$

So $$C=\frac{0-2-10-0}{3-0}=-4$$

SOL 1.6.86 Option (C) is correct.

Break away points

$$\frac{d\alpha}{ds}=0$$

$$\alpha=-\frac{1}{2}[s^3+12s^2+22s]$$

$$\frac{d\alpha}{ds}=-\frac{1}{2}[3s^2+24s+22]=0$$

$$s_1,s_2=-1.056,\ -6.9433$$

SOL 1.6.87 Option ( ) is correct.

SOL 1.6.88 Option (A) is correct.

Given state equation

$$\dot{X}=\begin{bmatrix}-3 & 1\\ 0 & -2\end{bmatrix}X$$

Or $$\dot{X}=AX,\ \text{where } A=\begin{bmatrix}-3 & 1\\ 0 & -2\end{bmatrix}$$

Taking Laplace transform on both sides.

$$sX(s)-X(0)=AX(s)$$

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$$X(s)(sI-A) = X(0)$$
$$X(s) = (sI-A)^{-1}X(0)$$

Steady state value of X is given by

$$x_{ss} = \lim_{s\to 0} sX(s) = \lim_{s\to 0} s(sI-A)^{-1}X(0)$$

$$(sI-A) = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} -3 & 1 \\ 0 & -2 \end{bmatrix} = \begin{bmatrix} s+3 & -1 \\ 0 & s+2 \end{bmatrix}$$

$$(sI-A^{-1}) = \frac{1}{(s+3)(s+2)}\begin{bmatrix} s+2 & 1 \\ 0 & s+3 \end{bmatrix}$$

$$= \begin{bmatrix} \frac{1}{(s+3)} & \frac{1}{(s+2)(s+3)} \\ 0 & \frac{1}{(s+2)} \end{bmatrix}$$

So the steady state value

$$x_{ss} = \lim_{s\to 0} s\begin{bmatrix} \frac{1}{(s+3)} & \frac{1}{(s+2)(s+3)} \\ 0 & \frac{1}{(s+2)} \end{bmatrix}\begin{bmatrix} 10 \\ -10 \end{bmatrix}$$

$$= \lim_{s\to 0} s\begin{bmatrix} \frac{10}{(s+3)} - \frac{10}{(s+2)(s+3)} \\ \frac{-10}{(s+2)} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

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SOL 1.6.89 Option (D) is correct.

Initial slope of the bode plot is -40 dB/dec. So no. of poles at origin is 2. Then slope increased by -20 dB/dec. at $\omega = 2$ rad/sec, so one poles lies at this frequency. At $\omega = 5$ rad/sec slope changes by $+20$ dB/dec, so there is one zero lying at this frequency. Further slope decrease by -20 dB/dec at $\omega = 25$ so one pole of the system is lying at this frequency.

Transfer function

$$H(s) = \frac{K(s+5)}{s^2(s+2)(s+25)}$$

At $\omega = 0.1$, gain is 54 dB, so

$$54 = 20\log\frac{5K}{(0.1)^2(2)(25)}$$

$$K = 50$$

$$H(s) = \frac{50(s+5)}{s^2(s+2)(s+25)}$$

SOL 1.6.90 Option (B) is correct.

Open loop transfer function of the system is

$$G(s) = \frac{10^4}{s(s+10)^2}$$

$$G(j\omega) = \frac{10^4}{j\omega(j\omega+10)^2} = \frac{10^4}{j\omega(100-\omega^2+j20\omega)}$$

Magnitude $\quad |G(j\omega)| = \dfrac{10^4}{\omega\sqrt{(100-\omega^2)^2+400\omega^2}}$

At $\omega = 20$ rad/sec

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$$|G(j20)| = \frac{10^4}{20\sqrt{9\times10^4+16\times10^4}}$$
$$= \frac{10^4}{20\times5\times10^2} = 1$$
$$\text{Magnitude in dB} = 20\log_{10}|G(j20)| = 20\log_{10}1 = 0 \text{ dB}$$

SOL 1.6.91 Option (C) is correct.

Since $|G(j\omega)| = 1$ at $\omega = 20$ rad/sec, So this is the gain cross-over frequency

$$\omega_g = 20 \text{ rad/sec}$$
$$\text{Phase margin} \quad \phi_{PM} = 180^\circ + \angle G(j\omega_g)$$
$$\angle G(j\omega_g) = -90^\circ - \tan^{-1}\left[\frac{20\,\omega_g}{100-\omega_g^2}\right]$$
$$\phi_{PM} = 180 - 90^\circ - \tan^{-1}\left[\frac{20\times20}{100-(20)^2}\right]$$
$$= -36.86^\circ$$

SOL 1.6.92 Option (C) is correct.

To calculate the gain margin, first we have to obtain phase cross over frequency (ω_p).

At phase cross over frequency

$$\angle G(j\omega_p) = -180^\circ$$
$$-90^\circ - \tan^{-1}\left[\frac{20\omega_p}{100-\omega_p^2}\right] = -180^\circ$$
$$\tan^{-1}\left[\frac{20\omega_p}{100-\omega_p^2}\right] = 90^\circ$$
$$100-\omega_p^2 = 0 \Rightarrow \omega_p = 10 \text{ rad/sec.}$$
$$\text{Gain margin in dB} = 20\log_{10}\left(\frac{1}{|G(j\omega_p)|}\right)$$
$$|G(j\omega_p)| = |G(j10)| = \frac{10^4}{10\sqrt{(100-100)^2+400(10)^2}}$$
$$= \frac{10^4}{10\times2\times10^2} = 5$$
$$\text{G.M.} = 20\log_{10}\left(\frac{1}{5}\right) = -13.97 \text{ dB}$$

SOL 1.6.93 Option (B) is correct.

Since gain margin and phase margin are negative, so the system is unstable.

SOL 1.6.94 Option (C) is correct.

Given characteristic equation

$$s^3+s^2+Ks+K = 0$$
$$1+\frac{K(s+1)}{s^3+s^2} = 0$$
$$1+\frac{K(s+1)}{s^2(s+2)} = 0$$

so open loop transfer function is

$$G(s) = \frac{K(s+1)}{s^2(s+1)}$$

root-locus is obtained in following steps:

1. Root-loci starts$(K=0)$ at $s=0$, $s=0$ and $s=-2$

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2. There is one zero at $s = -1$, so one of root-loci terminates at $s = -1$ and other two terminates at infinity
3. No. of poles $n = 3$, no of zeros ,$m = 1$
4. Break - Away points

$$\frac{dK}{ds} = 0$$

Asymptotes meets on real axis at a point C

$$C = \frac{\sum \text{poles} - \sum \text{zeros}}{n - m}$$

$$= \frac{(0 + 0 - 2) - (-1)}{3 - 1} = -0.5$$

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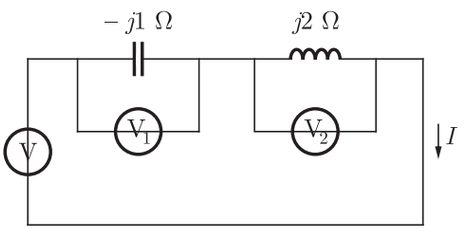
7

ELECTRICAL & ELECTRONIC MEASUREMENTS

YEAR 2013 — ONE MARK

MCQ 1.7.1 Three moving iron type voltmeters are connected as shown below. Voltmeter readings are V, V_1 and V_2 as indicated. The correct relation among the voltmeter readings is



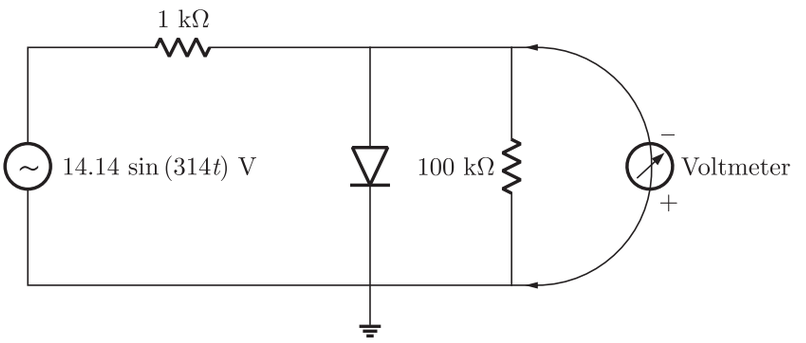
(A) $V = \dfrac{V_1}{\sqrt{2}} + \dfrac{V_2}{\sqrt{2}}$

(B) $V = V_1 + V_2$

(C) $V = V_1 V_2$

(D) $V = V_2 - V_1$

MCQ 1.7.2 The input impedance of the permanent magnet moving coil (PMMC) voltmeter is infinite. Assuming that the diode shown in the figure below is ideal, the reading of the voltmeter in Volts is



(A) 4.46

(B) 3.15

(C) 2.23

(D) 0

YEAR 2013 — TWO MARKS

MCQ 1.7.3 Two magnetically uncoupled inductive coils have Q factors q_1 and q_2 at the chosen operating frequency. Their respective resistances are R_1 and R_2. When connected in series, their effective Q factor at the same operating frequency is

(A) $q_1 + q_2$

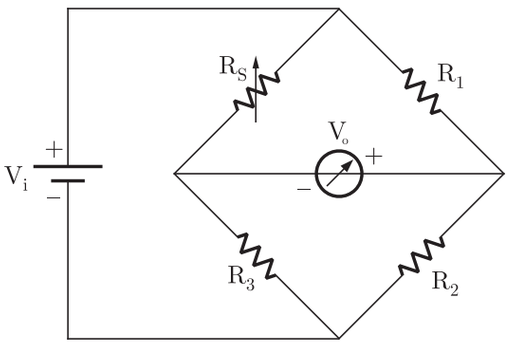
(B) $(1/q_1) + (1/q_2)$

(C) $(q_1 R_1 + q_2 R_2)/(R_1 + R_2)$

(D) $(q_1 R_2 + q_2 R_1)/(R_1 + R_2)$

MCQ 1.7.4 A strain gauge forms one arm of the bridge shown in the figure below and has a nominal resistance without any load as $R_s = 300\,\Omega$. Other bridge resistances are $R_1 = R_2 = R_3 = 300\,\Omega$. The maximum permissible current through the strain gauge is $20\,\text{mA}$. During certain measurement when the bridge is excited by

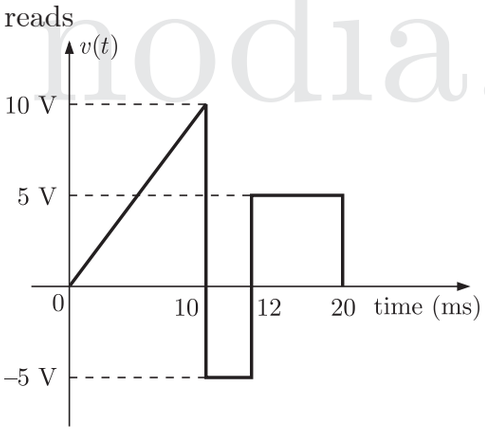
maximum permissible voltage and the strain gauge resistance is increased by 1% over the nominal value, the output voltage V_0 in mV is



(A) 56.02 (B) 40.83
(C) 29.85 (D) 10.02

YEAR 2012 ONE MARK

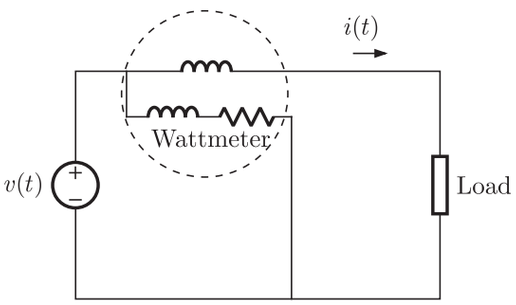
MCQ 1.7.5 A periodic voltage waveform observed on an oscilloscope across a load is shown. A permanent magnet moving coil (PMMC) meter connected across the same load reads



(A) 4 V (B) 5 V
(C) 8 V (D) 10 V

MCQ 1.7.6 The bridge method commonly used for finding mutual inductance is
(A) Heaviside Campbell bridge (B) Schering bridge
(C) De Sauty bridge (D) Wien bridge

MCQ 1.7.7 For the circuit shown in the figure, the voltage and current expressions are
$v(t) = E_1 \sin(\omega t) + E_3 \sin(3\omega t)$ and
$i(t) = I_1 \sin(\omega t - \phi_1) + I_3 \sin(3\omega t - \phi_3) + I_5 \sin(5\omega t)$
The average power measured by the wattmeter is



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(A) $\frac{1}{2}E_1I_1\cos\phi_1$

(B) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_1I_3\cos\phi_3 + E_1I_5]$

(C) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_3I_3\cos\phi_3]$

(D) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_3I_1\cos\phi_1]$

YEAR 2012 TWO MARKS

MCQ 1.7.8 An analog voltmeter uses external multiplier settings. With a multiplier setting of 20 kΩ, it reads 440 V and with a multiplier setting of 80 kΩ, it reads 352 V. For a multiplier setting of 40 kΩ, the voltmeter reads

(A) 371 V (B) 383 V

(C) 394 V (D) 406 V

YEAR 2011 ONE MARK

MCQ 1.7.9 Consider the following statement

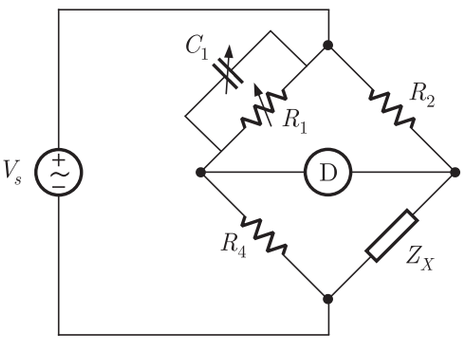
(1) The compensating coil of a low power factor wattmeter compensates the effect of the impedance of the current coil.

(2) The compensating coil of a low power factor wattmeter compensates the effect of the impedance of the voltage coil circuit.

(A) (1) is true but (2) is false (B) (1) is false but (2) is true

(C) both (1) and (2) are true (D) both (1) and (2) are false

MCQ 1.7.10 The bridge circuit shown in the figure below is used for the measurement of an unknown element Z_X. The bridge circuit is best suited when Z_X is a



(A) low resistance (B) high resistance

(C) low Q inductor (D) lossy capacitor

MCQ 1.7.11 A dual trace oscilloscope is set to operate in the ALTernate mode. The control input of the multiplexer used in the y-circuit is fed with a signal having a frequency equal to

(A) the highest frequency that the multiplexer can operate properly

(B) twice the frequency of the time base (sweep) oscillator

(C) the frequency of the time base (sweep) oscillator

(D) haif the frequency of the time base (sweep) oscillator

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YEAR 2011 TWO MARKS

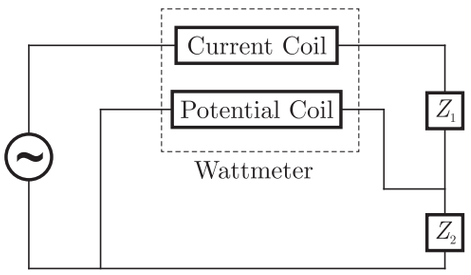
MCQ 1.7.12 A $4\frac{1}{2}$ digit DMM has the error specification as: 0.2% of reading + 10 counts. If a dc voltage of 100 V is read on its 200 V full scale, the maximum error that can be expected in the reading is

(A) $\pm 0.1\%$ (B) $\pm 0.2\%$

(C) $\pm 0.3\%$ (D) $\pm 0.4\%$

YEAR 2010 ONE MARK

MCQ 1.7.13 A wattmeter is connected as shown in figure. The wattmeter reads.



(A) Zero always

(B) Total power consumed by Z_1 and Z_2

(C) Power consumed by Z_1

(D) Power consumed by Z_2

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MCQ 1.7.14 An ammeter has a current range of 0-5 A, and its internal resistance is 0.2 Ω. In order to change the range to 0-25 A, we need to add a resistance of

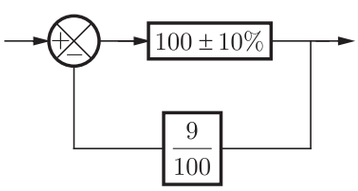
(A) 0.8 Ω in series with the meter

(B) 1.0 Ω in series with the meter

(C) 0.04 Ω in parallel with the meter

(D) 0.05 Ω in parallel with the meter

MCQ 1.7.15 As shown in the figure, a negative feedback system has an amplifier of gain 100 with $\pm 10\%$ tolerance in the forward path, and an attenuator of value 9/100 in the feedback path. The overall system gain is approximately :



(A) $10 \pm 1\%$ (B) $10 \pm 2\%$

(C) $10 \pm 5\%$ (D) $10 \pm 10\%$

YEAR 2010 TWO MARKS

MCQ 1.7.16 The Maxwell's bridge shown in the figure is at balance. The parameters of the inductive coil are.

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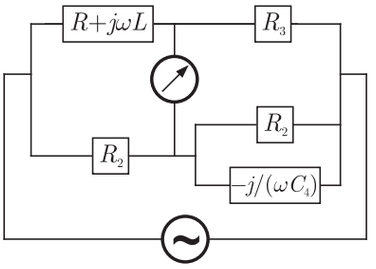


(A) $R = R_2R_3/R_4, L = C_4R_2R_3$
(B) $L = R_2R_3/R_4, R = C_4R_2R_3$
(C) $R = R_4/R_2R_3, L = 1/(C_4R_2R_3)$
(D) $L = R_4/R_2R_3, R = 1/(C_4R_2R_3)$

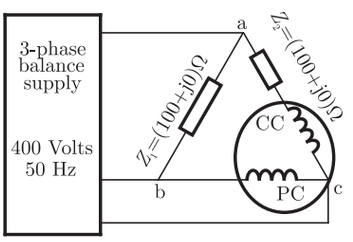
YEAR 2009 ONE MARK

MCQ 1.7.17 The pressure coil of a dynamometer type wattmeter is
(A) Highly inductive
(B) Highly resistive
(C) Purely resistive
(D) Purely inductive

MCQ 1.7.18 The two inputs of a CRO are fed with two stationary periodic signals. In the X-Y mode, the screen shows a figure which changes from ellipse to circle and back to ellipse with its major axis changing orientation slowly and repeatedly. The following inference can be made from this.
(A) The signals are not sinusoidal
(B) The amplitudes of the signals are very close but not equal
(C) The signals are sinusoidal with their frequencies very close but not equal
(D) There is a constant but small phase difference between the signals

YEAR 2009 TWO MARKS

MCQ 1.7.19 The figure shows a three-phase delta connected load supplied from a 400V, 50 Hz, 3-phase balanced source. The pressure coil (PC) and current coil (CC) of a wattmeter are connected to the load as shown, with the coil polarities suitably selected to ensure a positive deflection. The wattmeter reading will be



(A) 0
(B) 1600 Watt
(C) 800 Watt
(D) 400 Watt

MCQ 1.7.20 An average-reading digital multi-meter reads 10 V when fed with a triangular wave, symmetric about the time-axis. For the same input an rms-reading meter will read
(A) $\frac{20}{\sqrt{3}}$
(B) $\frac{10}{\sqrt{3}}$

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(C) $20\sqrt{3}$ (D) $10\sqrt{3}$

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MCQ 1.7.21 Two 8-bit ADCs, one of single slope integrating type and other of successive approximate type, take T_A and T_B times to convert 5 V analog input signal to equivalent digital output. If the input analog signal is reduced to 2.5 V, the approximate time taken by the two ADCs will respectively, be

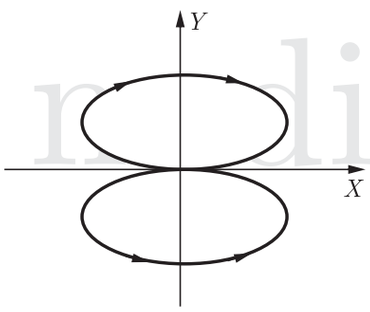
(A) T_A, T_B (B) $T_A/2, T_B$

(C) $T_A, T_B/2$ (D) $T_A/2, T_B/2$

YEAR 2008 TWO MARKS

MCQ 1.7.22 Two sinusoidal signals $p(\omega_1, t) = A\sin\omega_1 t$ and $q(\omega_2 t)$ are applied to X and Y inputs of a dual channel CRO. The Lissajous figure displayed on the screen shown below :

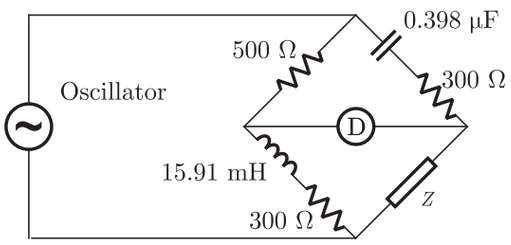
The signal $q(\omega_2 t)$ will be represented as



(A) $q(\omega_2 t) = A\sin\omega_2 t, \omega_2 = 2\omega_1$ (B) $q(\omega_2 t) = A\sin\omega_2 t, \omega_2 = \omega_1/2$

(C) $q(\omega_2 t) = A\cos\omega_2 t, \omega_2 = 2\omega_1$ (D) $q(\omega_2 t) = A\cos\omega_2 t, \omega_2 = \omega_1/2$

MCQ 1.7.23 The ac bridge shown in the figure is used to measure the impedance Z.



If the bridge is balanced for oscillator frequency $f = 2$ kHz, then the impedance Z will be

(A) $(260 + j0)\,\Omega$ (B) $(0 + j200)\,\Omega$

(C) $(260 - j200)\,\Omega$ (D) $(260 + j200)\,\Omega$

YEAR 2007 ONE MARK

MCQ 1.7.24 The probes of a non-isolated, two channel oscillocope are clipped to points A, B and C in the circuit of the adjacent figure. V_{in} is a square wave of a suitable low frequency. The display on Ch_1 and Ch_2 are as shown on the right. Then the "Signal" and "Ground" probes S_1, G_1 and S_2, G_2 of Ch_1 and Ch_2 respectively are connected to points :

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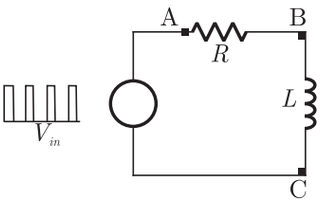
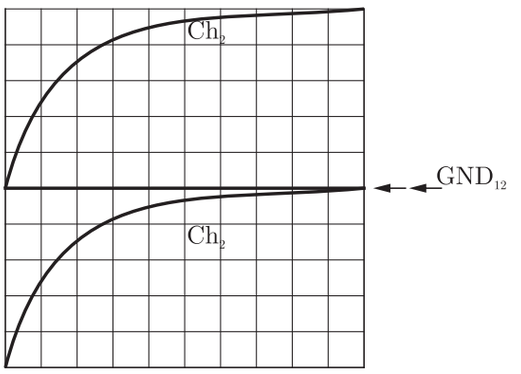
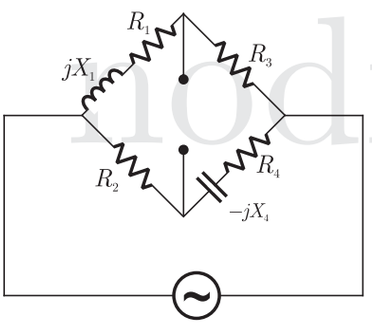




(A) A, B, C, A
(B) A, B, C, B
(C) C, B, A, B
(D) B, A, B, C

YEAR 2007 TWO MARKS

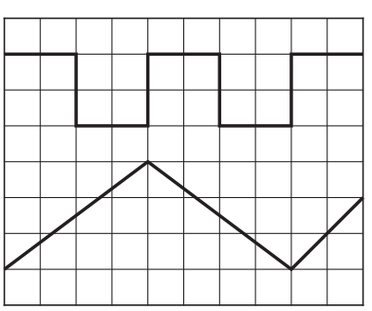
MCQ 1.7.25 A bridge circuit is shown in the figure below. Which one of the sequence given below is most suitable for balancing the bridge ?



(A) First adjust R_4, and then adjust R_1
(B) First adjust R_2, and then adjust R_3
(C) First adjust R_2, and then adjust R_4
(D) First adjust R_4, and then adjust R_2

YEAR 2006 ONE MARK

MCQ 1.7.26 The time/div and voltage/div axes of an oscilloscope have been erased. A student connects a 1 kHz, 5 V p-p square wave calibration pulse to channel-1 of the scope and observes the screen to be as shown in the upper trace of the figure. An unknown signal is connected to channel-2(lower trace) of the scope. It the time/div and V/div on both channels are the same, the amplitude (p-p) and period of the unknown signal are respectively



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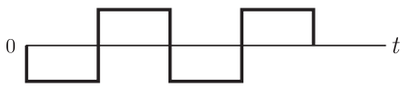
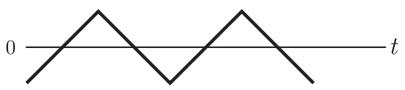
(A) 5 V, 1 ms (B) 5 V, 2 ms
(C) 7.5 V, 2 ms (D) 10 V, 1 ms

MCQ 1.7.27 A sampling wattmeter (that computes power from simultaneously sampled values of voltage and current) is used to measure the average power of a load. The peak to peak voltage of the square wave is 10 V and the current is a triangular wave of 5 A p-p as shown in the figure. The period is 20 ms. The reading in W will be





(A) 0 W (B) 25 W
(C) 50 W (D) 100 W

YEAR 2006 TWO MARKS

MCQ 1.7.28 A current of $-8+6\sqrt{2}\,(\sin\omega t+30^{\circ})$ A is passed through three meters. They are a centre zero PMMC meter, a true rms meter and a moving iron instrument. The respective reading (in A) will be

(A) 8, 6, 10 (B) 8, 6, 8
(C) -8,10,10 (D) -8,2,2

MCQ 1.7.29 A variable w is related to three other variables x, y, z as $w = xy/z$. The variables are measured with meters of accuracy $\pm 0.5\%$ reading, $\pm 1\%$ of full scale value and $\pm 1.5\%$ reading. The actual readings of the three meters are 80, 20 and 50 with 100 being the full scale value for all three. The maximum uncertainty in the measurement of w will be

(A) $\pm 0.5\%$ rdg (B) $\pm 5.5\%$ rdg
(C) ± 6.7 rdg (D) ± 7.0 rdg

MCQ 1.7.30 A 200/1 Current transformer (CT) is wound with 200 turns on the secondary on a toroidal core. When it carries a current of 160 A on the primary, the ratio and phase errors of the CT are found to be -0.5% and 30 minutes respectively. If the number of secondary turns is reduced by 1 new ratio-error(%) and phase-error(min) will be respectively

(A) 0.0,30 (B) -0.5,35
(C) -1.0,30 (D) -1.0,25

MCQ 1.7.31 R_1 and R_4 are the opposite arms of a Wheatstone bridge as are R_3 and R_2. The source voltage is applied across R_1 and R_3. Under balanced conditions which one of the following is true

(A) $R_1 = R_3R_4/R_2$
(B) $R_1 = R_2R_3/R_4$
(C) $R_1 = R_2R_4/R_3$
(D) $R_1 = R_2 + R_3 + R_4$

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MCQ 1.7.32 The Q-meter works on the principle of

(A) mutual inductance (B) self inductance

(C) series resonance (D) parallel resonance

MCQ 1.7.33 A PMMC voltmeter is connected across a series combination of DC voltage source $V_1 = 2$ V and AC voltage source $V_2(t) = 3\sin(4t)$ V. The meter reads

(A) 2 V (B) 5 V

(C) $(2+\sqrt{3}/2)$ V (D) $(\sqrt{17}/2)\,V$

MCQ 1.7.34 A digital-to-analog converter with a full-scale output voltage of 3.5 V has a resolution close to 14 mV. Its bit size is

(A) 4 (B) 8

(C) 16 (D) 32

YEAR 2005 TWO MARKS

MCQ 1.7.35 The simultaneous application of signals $x(t)$ and $y(t)$ to the horizontal and vertical plates, respectively, of an oscilloscope, produces a vertical figure-of-8 display. If P and Q are constants and $x(t) = \mathrm{P}\sin(4t + 30°)$, then $y(t)$ is equal to

(A) $\mathrm{Q}\sin(4t - 30°)$ (B) $\mathrm{Q}\sin(2t + 15°)$

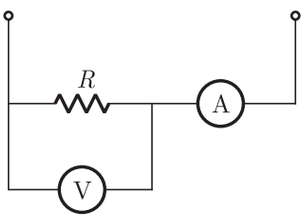
(C) $\mathrm{Q}\sin(8t + 60°)$ (D) $\mathrm{Q}\sin(4t + 30°)$

MCQ 1.7.36 A DC ammeter has a resistance of 0.1 Ω and its current range is 0-100 A. If the range is to be extended to 0-500 A, then meter required the following shunt resistance

(A) 0.010 Ω (B) 0.011 Ω

(C) 0.025 Ω (D) 1.0 Ω

MCQ 1.7.37 The set-up in the figure is used to measure resistance R .The ammeter and voltmeter resistances are 0.01Ω and 2000 Ω, respectively. Their readings are 2 A and 180 V, respectively, giving a measured resistances of 90 Ω The percentage error in the measurement is



(A) 2.25% (B) 2.35%

(C) 4.5% (D) 4.71%

MCQ 1.7.38 A 1000 V DC supply has two 1-core cables as its positive and negative leads : their insulation resistances to earth are 4 MΩ and 6 MΩ, respectively, as shown in the figure. A voltmeter with resistance 50 kΩ is used to measure the insulation of the cable. When connected between the positive core and earth, then voltmeter reads

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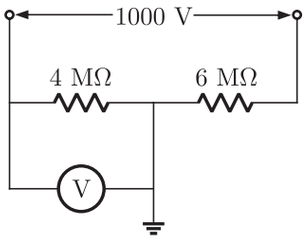

(A) 8 V (B) 16 V
(C) 24 V (D) 40 V

MCQ 1.7.39 Two wattmeters, which are connected to measure the total power on a three-phase system supplying a balanced load, read 10.5 kW and −2.5 kW, respectively. The total power and the power factor, respectively, are
(A) 13.0 kW, 0.334 (B) 13.0 kW, 0.684
(C) 8.0 kW, 0.52 (D) 8.0 kW, 0.334

YEAR 2004 ONE MARK

MCQ 1.7.40 A dc potentiometer is designed to measure up to about 2 V with a slide wire of 800 mm. A standard cell of emf 1.18 V obtains balance at 600 mm. A test cell is seen to obtain balance at 680 mm. The emf of the test cell is
(A) 1.00 V (B) 1.34 V
(C) 1.50 V (D) 1.70 V

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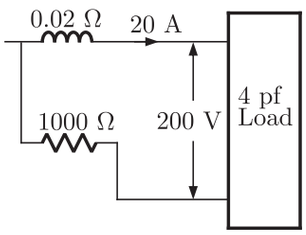
MCQ 1.7.41 The circuit in figure is used to measure the power consumed by the load. The current coil and the voltage coil of the wattmeter have 0.02 Ω and 1000Ω resistances respectively. The measured power compared to the load power will be



(A) 0.4 % less (B) 0.2% less
(C) 0.2% more (D) 0.4% more

MCQ 1.7.42 A galvanometer with a full scale current of 10 mA has a resistance of 1000 Ω. The multiplying power (the ratio of measured current to galvanometer current) of 100 Ω shunt with this galvanometer is
(A) 110 (B) 100
(C) 11 (D) 10

YEAR 2004 TWO MARKS

MCQ 1.7.43 A CRO probe has an impedance of 500 kΩ in parallel with a capacitance of 10 pF. The probe is used to measure the voltage between P and Q as shown in figure. The measured voltage will be

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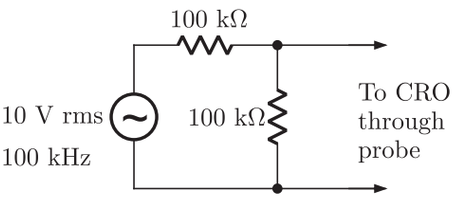


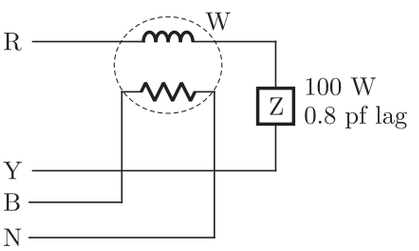
(A) 3.53 V (B) 4.37 V
(C) 4.54 V (D) 5.00 V

MCQ 1.7.44 A moving coil of a meter has 100 turns, and a length and depth of 10 mm and 20 mm respectively. It is positioned in a uniform radial flux density of 200 mT. The coil carries a current of 50 mA. The torque on the coil is
(A) 200 μNm (B) 100 μNm
(C) 2 μNm (D) 1 μNm

MCQ 1.7.45 A dc A-h meter is rated for 15 A, 250 V. The meter constant is 14.4 A-sec/rev. The meter constant at rated voltage may be expressed as
(A) 3750 rev/kWh (B) 3600 rev/kWh
(C) 1000 rev/kWh (D) 960 rev/kWh

MCQ 1.7.46 A moving iron ammeter produces a full scale torque of 240 μNm with a deflection of 120¢ at a current of 10 A . The rate of change of self induction (μH/radian) of the instrument at full scale is
(A) 2.0 μH/radian (B) 4.8 μH/radian
(C) 12.0 μH/radian (D) 114.6 μH/radian

MCQ 1.7.47 A single-phase load is connected between R and Y terminals of a 415 V, symmetrical, 3-phase, 4-wire system with phase sequence RYB. A wattmeter is connected in the system as shown in figure. The power factor of the load is 0.8 lagging. The wattmeter will read



(A) −795 W (B) −597 W
(C) +597 W (D) +795 W

MCQ 1.7.48 A 50 Hz, bar primary CT has a secondary with 500 turns. The secondary supplies 5 A current into a purely resistive burden of 1 Ω. The magnetizing ampere-turns is 200. The phase angle between the primary and second current is
(A) 4.6¢ (B) 85.4¢
(C) 94.6¢ (D) 175.4¢

MCQ 1.7.49 The core flux in the CT of Prob Q.44, under the given operating conditions is
(A) 0 (B) 45.0 μWb
(C) 22.5 mWb (D) 100.0 mWb

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MCQ 1.7.50 A Manganin swap resistance is connected in series with a moving coil ammeter consisting of a milli-ammeter and a suitable shunt in order to

(A) minimise the effect of temperature variation

(B) obtain large deflecting torque

(C) reduce the size of the meter

(D) minimise the effect of stray magnetic fields

MCQ 1.7.51 The effect of stray magnetic field on the actuating torque of a portable instrument is maximum when the operating field of the instrument and the stray fields are

(A) perpendicular (B) parallel

(C) inclined at 60° (D) inclined at 30°

MCQ 1.7.52 A reading of 120 is obtained when standard inductor was connected in the circuit of a Q-meter and the variable capacitor is adjusted to value of 300 pF. A lossless capacitor of unknown value C_x is then connected in parallel with the variable capacitor and the same reading was obtained when the variable capacitor is readjusted to a value of 200 pF. The value of C_x in pF is

(A) 100 (B) 200

(C) 300 (D) 500

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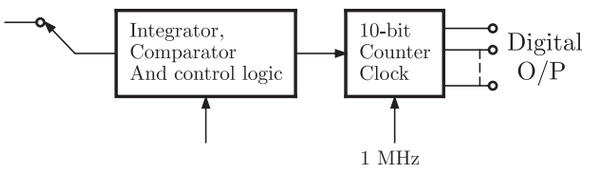
YEAR 2003 TWO MARKS

MCQ 1.7.53 The simplified block diagram of a 10-bit A/D converter of dual slope integrator type is shown in figure. The 10-bit counter at the output is clocked by a 1 MHz clock. Assuming negligible timing overhead for the control logic, the maximum frequency of the analog signal that can be converted using this A/D converter is approximately



(A) 2 kHz (B) 1 kHz

(C) 500 Hz (D) 250 Hz

MCQ 1.7.54 The items in Group-I represent the various types of measurements to be made with a reasonable accuracy using a suitable bridge. The items in Group-II represent the various bridges available for this purpose. Select the correct choice of the item in Group-II for the corresponding item in Group-I from the following

	List-I		List-II
P.	Resistance in the milli-ohm range	1.	Wheatstone Bridge
Q.	Low values of Capacitance	2.	Kelvin Double Bridge
R.	Comparison of resistance which are nearly equal	3.	Schering Bridge

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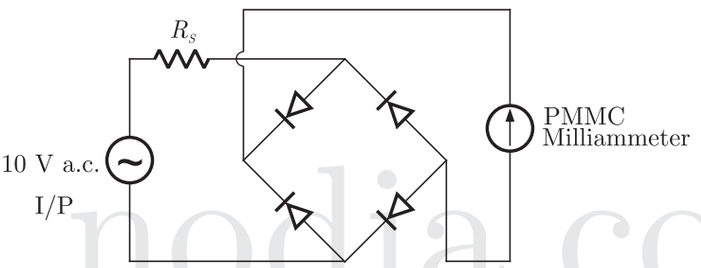
S. Inductance of a coil with a large time-constant

4. Wien's Bridge
5. Hay's Bridge
6. Carey-Foster Bridge

Codes :

(A) P=2, Q=3, R=6, S=5
(B) P=2, Q=6, R=4, S=5
(C) P=2, Q= 3, R=5, S=4
(D) P=1, Q=3, R=2, S=6

MCQ 1.7.55 A rectifier type ac voltmeter of a series resistance R_s, an ideal full-wave rectifier bridge and a PMMC instrument as shown in figure. The internal. resistance of the instrument is 100 Ω and a full scale deflection is produced by a dc current of 1 mA. The value of R_s required to obtain full scale deflection with an ac voltage of 100 V (rms) applied to the input terminals is



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(A) 63.56 Ω
(B) 69.93 Ω
(C) 89.93 Ω
(D) 141.3 kΩ

MCQ 1.7.56 A wattmeter reads 400 W when its current coil is connected in the R-phase and its pressure coil is connected between this phase and the neutral of a symmetrical 3-phase system supplying a balanced star connected 0.8 p.f. inductive load. This phase sequence is RYB. What will be the reading of this wattmeter if its pressure coil alone is reconnected between the B and Y phases, all other connections remaining as before ?

(A) 400.0
(B) 519.6
(C) 300.0
(D) 692.8

MCQ 1.7.57 The inductance of a certain moving-iron ammeter is expressed as $L = 10 + 3\theta - (\theta^2/4)\,\mu H$, where θ is the deflection in radians from the zero position. The control spring torque is $25 \# 10^{-6}$ Nm/radian. The deflection of the pointer in radian when the meter carries a current of 5 A, is

(A) 2.4
(B) 2.0
(C) 1.2
(D) 1.0

MCQ 1.7.58 A 500A/5A, 50 Hz transformer has a bar primary. The secondary burden is a pure resistance of 1 Ω and it draws a current of 5 A. If the magnetic core requires 250 AT for magnetization, the percentage ratio error is

(A) 10.56
(B) −10.56
(C) 11.80
(D) −11.80

MCQ 1.7.59 The voltage-flux adjustment of a certain 1-phase 220 V induction watt-hour meter is altered so that the phase angle between the applied voltage and the flux due to it is 85c(instead of 90c). The errors introduced in the reading of this meter when the current is 5 A at power factor of unity and 0.5 lagging are respectively

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(A) 3.8 mW, 77.4 mW (B) −3.8 mW, −77.4 mW

(C) −4.2 W, −85.1 W (D) 4.2 W, 85.1 W

MCQ 1.7.60 Group-II represents the figures obtained on a CRO screen when the voltage signals $V_x = V_{xm}\sin\omega t$ and $V_y = V_{ym}\sin(\omega t + \Phi)$ are given to its X and Y plates respectively and Φ is changed. Choose the correct value of Φ from Group-I to match with the corresponding figure of Group-II.

Group-I

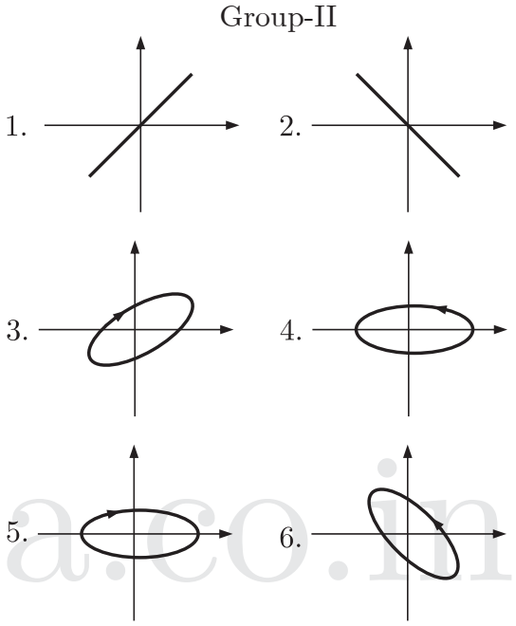
P. $\Phi = 0$

Q. $\Phi = \pi/2$

R. $\pi < \Phi < 3\pi/2$

S. $\Phi = 3\pi/2$

Group-II



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Codes :

(A) P=1, Q= 3, R=6, S=5 (B) P=2, Q=6, R=4, S=5

(C) P=2, Q= 3, R=5, S=4 (D) P=1, Q=5, R=6, S=4

YEAR 2002 ONE MARK

MCQ 1.7.61 Two in-phase, 50 Hz sinusoidal waveforms of unit amplitude are fed into channel-1 and channel-2 respectively of an oscilloscope. Assuming that the voltage scale, time scale and other settings are exactly the same for both the channels, what would be observed if the oscilloscope is operated in X-Y mode ?

(A) A circle of unit radius (B) An ellipse

(C) A parabola

(D) A straight line inclined at 45° with respect to the x-axis.

MCQ 1.7.62 The line-to-line input voltage to the 3-phase, 50 Hz, ac circuit shown in Figure is 100 V rms. Assuming that the phase sequence is RYB, the wattmeters would read.

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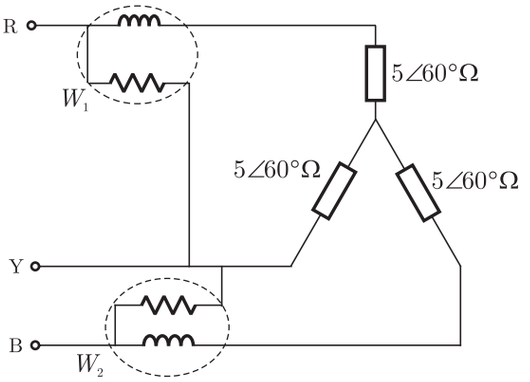

(A) W_1=886 W and W_2=886 W
(B) W_1=500 W and W_2 =500 W
(C) W_1=0 W and W_2=1000 W
(D) W_1 =250 W and W_2 =750 W

YEAR 2001 ONE MARK

MCQ 1.7.63 If an energy meter disc makes 10 revolutions in 100 seconds when a load of 450 W is connected to it, the meter constant (in rev/kWh) is
(A) 1000
(B) 500
(C) 1600
(D) 800

MCQ 1.7.64 The minimum number of wattmeter(s) required to measure 3-phase, 2-wire balanced or unbalanced power is
(A) 1
(B) 2
(C) 3
(D) 4

MCQ 1.7.65 A 100 μA ammeter has an internal resistance of 100 Ω. For extending its range to measure 500 μA, the shunt required is of resistance (in Ω)
(A) 20.0
(B) 22.22
(C) 25.0
(D) 50.0

MCQ 1.7.66 Resistance R_1 and R_2 have, respectively, nominal values of 10 Ω and 5 Ω, and tolerance of $\pm 5\%$ and $\pm 10\%$. The range of values for the parallel combination of R_1 and R_2 is
(A) 3.077 Ω to 3.636 Ω
(B) 2.805 Ω to 3.371 Ω
(C) 3.237 Ω to 3.678 Ω
(D) 3.192 Ω to 3.435 Ω

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SOLUTIONS

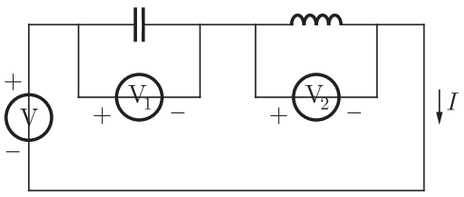
SOL 1.7.1 Option (B) is correct.

For an ideal voltmeter interval resistance is always zero. So we can apply the KVL along the two voltmeters as

$$V - V_1 - V_2 = 0$$

or

$$V = V_1 + V_2$$



SOL 1.7.2 Option (A) is correct.

For the +ve half cycle of I/p voltage, diode will be forward biased ($V_\gamma = 0$, ideal diode) Therefore, the voltmeter will be short circuited and reads

$$V_1 = 0 \text{ volt} \qquad \text{(for +ve half cycle)}$$

Now, for −ve half cycle, diode will be reverse biased and treated as open circuit. So, the voltmeter reads the voltage across 100 kΩ. Which is given by

$$V_2 = 100 \times \frac{14.14\angle 0^\circ}{100+1}$$

So,

$$V_{2,rms} = \frac{14}{\sqrt{2}} \text{volt}$$

Therefore, the average voltage for the whole time period is obtained as

$$V_{ave} = \frac{V_1 + V_{2,rms}}{2} = \frac{0 + (14/\sqrt{2})}{2} = \frac{14}{2\sqrt{2}}$$
$$= 4.94 \approx 4.46 \text{ volt}$$

SOL 1.7.3 Option (C) is correct.

The quality factor of the inductances are given by

$$q_1 = \frac{\omega L_1}{R_1}$$

and

$$q_2 = \frac{\omega L_2}{R_2}$$

So, in series circuit, the effective quality factor is given by

$$Q = \frac{|X_{Leq}|}{R_{eq}} = \frac{\omega L_1 + \omega L_2}{R_1 + R_2}$$
$$= \frac{\frac{\omega L_1}{R_1 R_2} + \frac{\omega L_2}{R_1 R_2}}{\frac{1}{R_2} + \frac{1}{R_1}}$$
$$= \frac{\frac{q_1}{R_2} + \frac{q_2}{R_2}}{\frac{1}{R_2} + \frac{1}{R_1}}$$

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$$= \frac{q_1 R_1 + q_2 R_2}{R_1 + R_2}$$

SOL 1.7.4 Option (C) is correct.

SOL 1.7.5 Option (A) is correct.

PMMC instrument reads average (dc) value.

$$V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt = \frac{1}{20 \times 10^{-3}}\int_0^{20} v(t)\,dt$$

$$= \frac{1}{20}\left[\int_0^{10} t\,dt + \int_{10}^{12}(-5)\,dt + \int_{12}^{20} 5\,dt\right]$$

$$= \frac{1}{20}\left(\left[\frac{t^2}{2}\right]_0^{10} - 5\left[t\right]_{10}^{12} + 5\left[t\right]_{12}^{20}\right)$$

$$= \frac{1}{20}[50 - 5(2) + 5(8)] = \frac{80}{20} = 4\text{ V}$$

SOL 1.7.6 Option (A) is correct.

Heaviside mutual inductance bridge measures mutual inductance is terms of a known self-inductance.

SOL 1.7.7 Option (C) is correct.

Let $\omega t = \theta$, we have instaneous voltage and current as follows.

$$v(t) = E_1 \sin\theta + E_3 \sin 3\theta$$
$$i(t) = I_1 \sin(\theta - \phi_1) + I_3 \sin(3\theta - \phi_3) + I_5 \sin(5\theta)$$

We know that wattmeter reads the average power, which is gives as

$$P = \frac{1}{2\pi}\int_0^{2\pi} v(t)\,i(t)\,d\theta \qquad \ldots(\text{i})$$

We can solve this integration using following results.

(i) $\frac{1}{2\pi}\int_0^{2\pi} A\sin(\theta+\alpha)\cdot B\sin(\theta+\beta)\,d\theta = \frac{1}{2}AB\cos(\alpha-\beta)$

(ii) $\frac{1}{2\pi}\int_0^{2\pi} A\sin(\theta+\alpha)\cdot B\cos(\theta+\alpha)\,d\theta = \frac{1}{2}AB\sin(\alpha-\beta)$

(iii) $\frac{1}{2\pi}\int_0^{2\pi} A\sin(m\theta+\alpha)\cdot B\cos(n\theta+\beta)\,d\theta = 0$

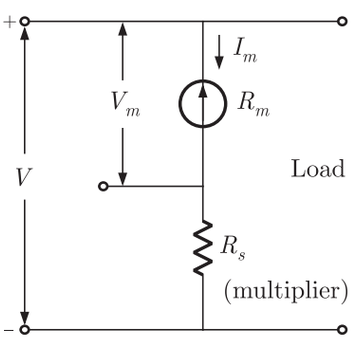
(iv) $\frac{1}{2\pi}\int_0^{2\pi} A\sin(m\theta+\alpha)\cdot B\cos(n\theta+\beta)\,d\theta = 0$

Result (iii) and (iv) implies that power is transferred between same harmonics of voltages and currents. Thus integration of equation (i) gives.

$$P = \frac{1}{2}E_1 I_1 \cos\phi + \frac{1}{2}E_3 I_3 \cos\phi_3$$

SOL 1.7.8 Option (D) is correct.

A voltmeter with a multiplier is shown in figure below.



Here I_m = Fully scale deflection current of meter.

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$$R_m = \text{Internal resistance of meter}$$
$$R_s = \text{Voltage across the meter}$$
$$V = \text{Full range voltage of instrument}$$
$$V_m = I_m R_m$$
$$V = I_m (R_m + R_s)$$
$$\frac{V}{V_m} = \frac{R_m + R_s}{R_m} = 1 + \frac{R_s}{R_m}$$

Here when, $R_{s1} = 20\,\text{k}\Omega,\ V_{m1} = 440\,\text{V}$

So, $$\frac{V}{440} = 1 + \frac{20\text{k}}{R_m} \qquad \text{...(i)}$$

When, $R_{s2} = 80\,\text{k}\Omega,\ V_{m2} = 352\,\text{V}$

So, $$\frac{V}{352} = 1 + \frac{80\,\text{k}}{R_m} \qquad \text{...(ii)}$$

Solving equation (i) and (ii), we get

$$V = 480\,\text{V},\ R_m = 220\,\text{k}\Omega$$

So when $R_{s3} = 40\,\text{k}\Omega,\ V_{m3} = ?$

$$\frac{480}{V_{m3}} = 1 + \frac{40\text{k}}{220\text{k}} \quad \Rightarrow\ V_{m2} \simeq 406\,\text{V}$$

SOL 1.7.9 Option (A) is correct.

The compensating coil compensation the effect of impedance of current coil.

SOL 1.7.10 Option (C) is correct.

Let $Z_1 = R_1 \,||\, j\omega C_1$

so admittance $Y_1 = \frac{1}{Z_1} = \frac{1}{R_1} + j\omega C_1$

$$Z_2 = R_2 \ \text{ and } Z_4 = R_4$$

Let $Z_X = R_X + j\omega L_X$ (Unknown impedance)

For current balance condition of the Bridge

$$Z_2 Z_4 = Z_X Z_1 = \frac{Z_X}{Y_1}$$

Let $$Z_X = Z_2 Z_4 Y_1$$

$$R_X + j\omega L_X = R_2 R_4 \left(\frac{1}{R_1} + j\omega C_1\right)$$

Equating imaginary and real parts

$$R_X = \frac{R_2 R_4}{R_1} \quad \text{and } L_X = R_2 R_4 C_1$$

Quality factor of inductance which is being measured

$$Q = \frac{\omega L_X}{R_X} = \omega R_1 C_1$$

From above equation we can see that for measuring high values of Q we need a large value of resistance R_4 which is not suitable. This bridge is used for measuring low Q coils.

Note: We can observe directly that this is a maxwell's bridge which is suitable for low values of Q (i.e. $Q < 10$)

SOL 1.7.11 Option (C) is correct.

In the alternate mode it switches between channel A and channel B, letting each through for one cycle of horizontal sweep as shown in the figure.

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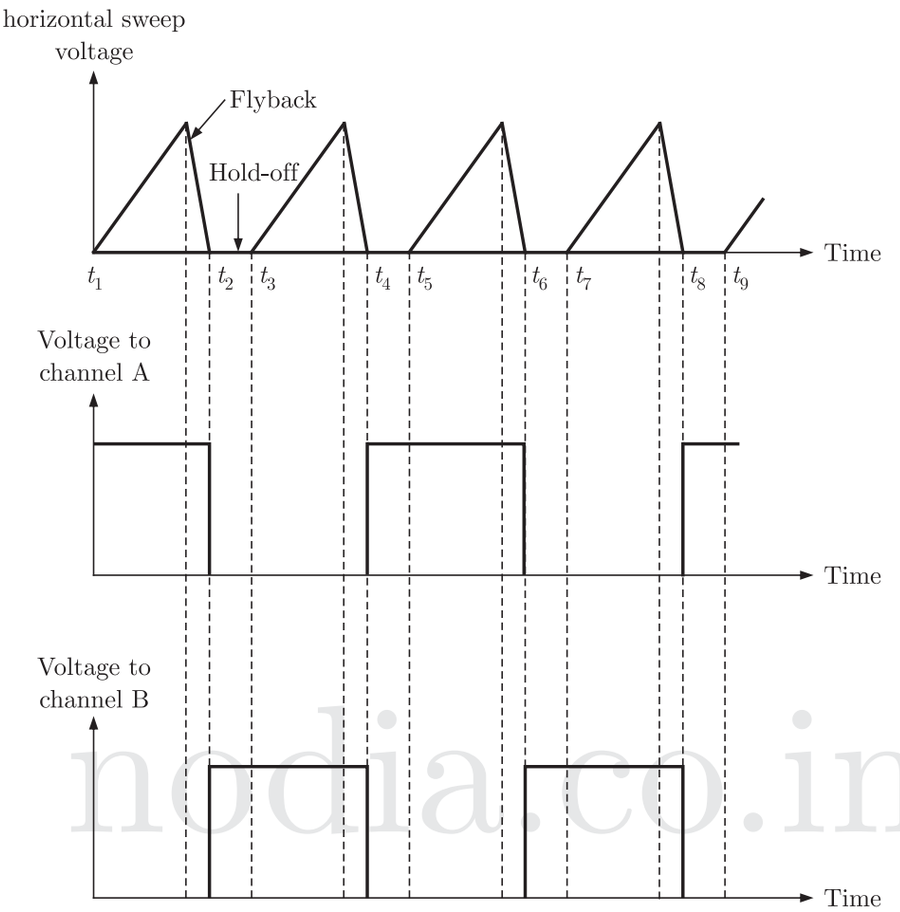

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SOL 1.7.12 Option (C) is correct.

$4\frac{1}{2}$ digit display will read from 000.00 to 199.99 So error of 10 counts is equal to $= \pm 0.10$ V

For 100 V, the maximum error is

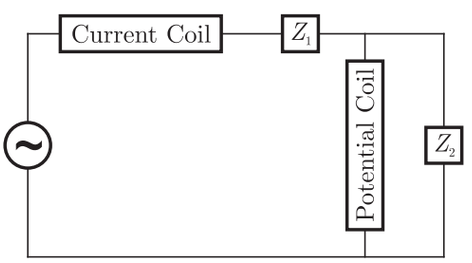
$$e = \pm (100 \times 0.002 + 0.1) = \pm 0.3 \text{ V}$$

Percentage error

$$= \pm \frac{0.3 \times 100}{100}\% = \pm 0.3\,\% \text{ of reading}$$

SOL 1.7.13 Option (D) is correct.

Since potential coil is applied across Z_2 as shown below



Wattmeter read power consumed by Z_2

SOL 1.7.14 Option (D) is correct.

Given that full scale current is 5 A

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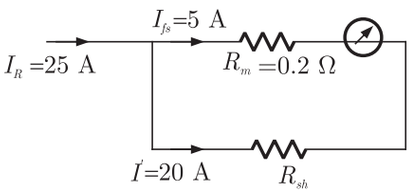

Current in shunt $I' = I_R - I_{fs} = 25 - 5 = 20$ A

$$20 \times R_{sh} = 5 \times 0.2$$

$$R_{sh} = \frac{1}{20} = .05\,\Omega$$

SOL 1.7.15 Option (A) is correct.

Overall gain of the system is

$$g = \frac{100}{1 + 100\left(\frac{9}{100}\right)} = 10 \text{ (zero error)}$$

Gain with error

$$g = \frac{100 + 10\%}{1 + (100 + 10\%)\left(\frac{9}{100}\right)} = \frac{110}{1 + \frac{110 \times 9}{100}} = 10.091$$

$$\text{error } \Delta g = 10.091 - 10 \simeq 0.1$$

Similarly

$$g = \frac{100 - 10\%}{1 + (100 - 10\%)\frac{9}{100}} = \frac{90}{1 + 90 \times \frac{9}{100}}$$

$$= 9.89$$

$$\text{error } \Delta g = 9.89 - 10 \simeq -0.1$$

$$\text{So gain } g = 10 \pm 0.1 = 10 \pm 1\%$$

SOL 1.7.16 Option (A) is correct.

At balance condition

$$(R + j\omega L)\left(R_4 \parallel \frac{-j}{\omega C_4}\right) = R_2 R_3$$

$$(R + j\omega L)\frac{\frac{-jR_4}{\omega C_4}}{\left(R_4 - \frac{j}{\omega C_4}\right)} = R_2 R_3$$

$$\frac{-jRR_4}{\omega C_4} + \frac{\omega L R_4}{\omega C_4} = R_2 R_3 R_4 - \frac{jR_2 R_3}{\omega C_4}$$

$$\frac{-jRR_4}{\omega C_4} + \frac{LR_4}{C_4} = R_2 R_3 R_4 - \frac{jR_2 R_3}{\omega C_4}$$

Comparing real & imaginary parts.

$$\frac{RR_4}{\omega C_4} = \frac{R_2 R_3}{\omega C_4}$$

$$R = \frac{R_2 R_3}{R_4}$$

Similarly,

$$\frac{LR_4}{C_4} = R_2 R_3 R_4$$

$$L = R_2 R_3 C_4$$

SOL 1.7.17 Option (B) is correct.

Since Potential coil is connected across the load terminal, so it should be highly

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resistive, so that all the voltage appears across load.

SOL 1.7.18 Option (D) is correct.

A circle is produced when there is a 90° phase difference between vertical and horizontal inputs.

SOL 1.7.19 Option (C) is correct.

Wattmeter reading $P = V_{PC} I_{CC}$

$V_{PC} \rightarrow$ Voltage across potential coil.

$I_{CC} \rightarrow$ Current in current coil.

$$V_{PC} = V_{bc} = 400\angle -120^\circ$$

$$I_{CC} = I_{ac} = \frac{400\angle 120^\circ}{100} = 4\angle 120^\circ$$

Power
$$P = 400\angle -120^\circ \times 4\angle 120^\circ$$
$$= 1600\angle 240^\circ = 1600 \times \frac{1}{2} = 800 \text{ Watt}$$

SOL 1.7.20 Option (D) is correct.

Average value of a triangular wave

$$V_{av} = \frac{V_m}{3}$$

$$\text{rms value } V_{ms} = \frac{V_m}{\sqrt{3}}$$

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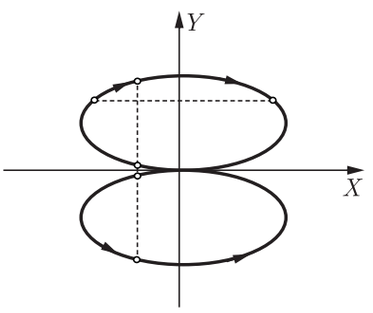
Given that
$$V_{av} = \frac{V_m}{3} = 10 \text{ V}$$

So
$$V_{rms} = \frac{V_m}{\sqrt{3}} = \sqrt{3}\, V_{av} = 10\sqrt{3} \text{ V}$$

SOL 1.7.21 Option (A) is correct.

Conversion time does not depend on input voltage so it remains same for both type of ADCs.

SOL 1.7.22 Option (D) is correct.



Frequency ratio
$$\frac{f_Y}{f_X} = \frac{\text{meeting points of horizontal tangents}}{\text{meeting points of vertical tangents}}$$

$$\frac{f_Y}{f_X} = \frac{2}{4}$$

$$f_Y = \frac{1}{2}(f_X)$$

$$\omega_2 = \omega_1/2$$

Since the Lissajous figures are ellipse, so there is a phase difference of 90° exists between vertical and horizontal inputs.

So
$$q(\omega_2 t) = A\cos\omega_2 t,\ \omega_2 = \omega_1/2$$

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SOL 1.7.23 Option (A) is correct.

Impedance of different branches is given as

$$\begin{aligned} Z_{AB} &= 500\ \Omega \\ Z_{BC} &= \frac{1}{j \times 2\pi \times 2 \times 10^3 \times 0.398\,\mu F} + 300\ \Omega \\ &\simeq (-200j + 300)\ \Omega \\ Z_{AD} &= j \times 2\pi \times 2 \times 10^3 \times 15.91\,\text{mH} + 300\,\Omega \\ &\simeq (200j + 300)\ \Omega \end{aligned}$$

To balance the bridge

$$\begin{aligned} Z_{AB}Z_{CD} &= Z_{AD}Z_{BC} \\ 500Z &= (200j + 300)(-200j + 300) \\ 500Z &= 130000 \\ Z &= (260 + j0)\ \Omega \end{aligned}$$

SOL 1.7.24 Option (B) is correct.

Since both the waveform appeared across resistor and inductor are same so the common point is B. Signal Probe S_1 is connecte with A, S_2 is connected with C and both the grount probes G_1 and G_2 are connected with common point B.

SOL 1.7.25 Option (A) is correct.

To balance the bridge

$$(R_1 + jX_1)(R_4 - jX_4) = R_2R_3$$

$$(R_1R_4 + X_1X_4) + j(X_1R_4 - R_1X_4) = R_2R_3$$

comparing real and imaginary parts on both sides of equations

$$R_1R_4 + X_1X_4 = R_2R_3 \qquad ...(1)$$

$$X_1R_4 - R_1X_4 = 0 \Rightarrow \frac{X_1}{X_4} = \frac{R_1}{R_4} \qquad ...(2)$$

from eq(1) and (2) it is clear that for balancing the bridge first balance R_4 and then R_1.

SOL 1.7.26 Option (C) is correct.

From the Calibration pulse we can obtain

$$\frac{\text{Voltage}}{\text{Division}}(\triangle\ \text{V}) = \frac{5}{2} = 2.5\ \text{V}$$

$$\frac{\text{Time}}{\text{Division}}(\triangle\ \text{T}) = \frac{1\ \text{ms}}{4} = \frac{1}{4}\ \text{msec}$$

So amplitude (p-p) of unknown signal is

$$V_{\text{P-P}} = \triangle\ \text{V} \times 5 = 2.5 \times 5 = 7.5\ \text{V}$$

$$\text{Time period } T = \triangle\ \text{T} \times 8 = \frac{1}{4} \times 8 = 2\ \text{ms}$$

SOL 1.7.27 Option (A) is correct.

Reading of wattmeter (Power) in the circuit

$$P_{av} = \frac{1}{T}\int_0^T VIdt = \text{Common are between } V - I$$

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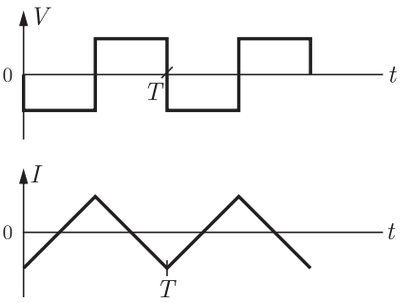

total common area = 0 (Positive and negative area are equal)
So $P_{av} = 0$

SOL 1.7.28 Option (C) is correct.
PMMC instrument reads only dc value so

$$I_{\text{PMMC}} = -8 \text{ A}$$

rms meter reads rms value so

$$I_{rms} = \sqrt{(-8)^2 + \frac{(6\sqrt{2})^2}{2}}$$

$$= \sqrt{64 + 36} = 10 \text{ A}$$

Moving iron instrument also reads rms value of current So

$$I_{\text{MI}} = 10 \text{ mA}$$

Reading are $(I_{\text{PMMC}}, I_{rms}, I_{\text{MI}}) = (-8 \text{ A}, 10 \text{ A}, 10 \text{ A})$

SOL 1.7.29 Option (D) is correct.

$$\text{Given that } \omega = \frac{xy}{z}$$

$$\log \omega = \log x + \log y - \log z$$

Maximum error in ω

$$\%\frac{d\omega}{\omega} = \pm\frac{dx}{x} \pm \frac{dy}{y} \pm \frac{dz}{z}$$

$$\frac{dx}{x} = \pm 0.5\% \text{ reading}$$

$$\frac{dy}{y} = \pm 1\% \text{ full scale}$$

$$= \pm\frac{1}{100} \times 100 = \pm 1$$

$$\frac{dy}{y} = \pm\frac{1}{20} \times 100 = \pm 5\% \text{ reading}$$

$$\frac{dz}{z} = 1.5\% \text{ reading}$$

So $$\%\frac{d\omega}{\omega} = \pm 0.5\% \pm 5\% \pm 1.5\% = \pm 7\%$$

SOL 1.7.30 Option ( ) is correct.

SOL 1.7.31 Option (B) is correct.

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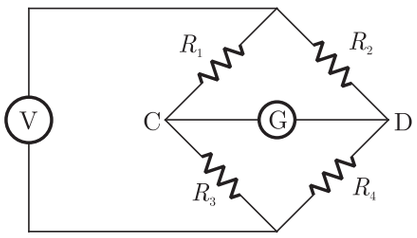


In balanced condition there is no current in CD arm so $V_C = V_D$
Writing node equation at C and D

$$\frac{V_C - V}{R_1} + \frac{V_C}{R_3} = 0 \Rightarrow V_C = V\left(\frac{R_3}{R_1 + R_3}\right)$$

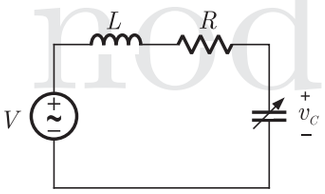
$$\frac{V_0 - V}{R_2} + \frac{V_D}{R_4} = 0 \Rightarrow V_D = V\left(\frac{R_4}{R_2 + R_4}\right)$$

So
$$V\left(\frac{R_3}{R_1 + R_3}\right) = V\left(\frac{R_4}{R_2 + R_4}\right)$$

$$R_2R_3 + R_3R_4 = R_1R_4 + R_3R_4$$

$$R_1 = R_2R_3/R_4$$

SOL 1.7.32 Option (C) is correct.
Q-meter works on the principle of series resonance.



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$$\text{At resonance } V_C = V_L$$

$$\text{and } I = \frac{V}{R}$$

$$\text{Quality factor Q} = \frac{\omega L}{R} = \frac{1}{\omega CR} = \frac{\omega L \times I}{R \times I} = \frac{V_L}{E} = \frac{V_C}{E}$$

Thus, we can obtain Q

SOL 1.7.33 Option (A) is correct.
PMMC instruments reads DC value only so it reads 2 V.

SOL 1.7.34 Option (B) is correct.

$$\text{Resolution of n-bit DAC} = \frac{V_{fs}}{2^n - 1}$$

So
$$14\,mv = \frac{3.5\text{ V}}{2^n - 1}$$

$$2^n - 1 = \frac{3.5}{14 \times 10^{-3}}$$

$$2^n - 1 = 250$$

$$2^n = 251$$

$$n = 8 \text{ bit}$$

SOL 1.7.35 Option (B) is correct.
We can obtain the frequency ratio as following

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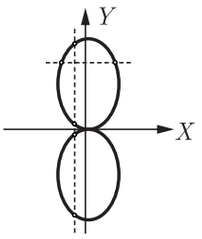


$$\frac{f_Y}{f_X} = \frac{\text{meeting points of horizontal tangents}}{\text{meeting points of vertical tangents}}$$

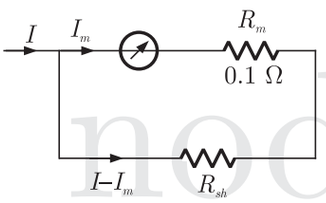
$$\frac{f_Y}{f_X} = \frac{2}{4}$$

$$f_Y = \frac{1}{2} f_X$$

There should exist a phase difference(15°) also to produce exact figure of-8.

SOL 1.7.36 Option (C) is correct.

The configuration is shown below



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It is given that $I_m = 100$ A

Range is to be extended to $0 - 500$ A,

$$I = 500 \text{ A}$$

So,

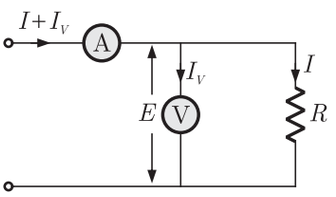
$$I_m R_m = (I - I_m) R_{sh}$$

$$100 \times 0.1 = (500 - 100) R_{sh}$$

$$R_{sh} = \frac{100 \times 0.1}{400} = 0.025 \ \Omega$$

SOL 1.7.37 Option (D) is correct.

The configuration is shown below



Current in voltmeter is given by

$$I_V = \frac{E}{2000} = \frac{180}{2000} = .09 \text{ A}$$

$$I + I_V = 2 \text{ amp}$$

So $$\text{I} = 2 - .09 = 1.91 \text{ V}$$

$$R = \frac{E}{I} = \frac{180}{1.91} = 94.24 \ \Omega$$

Ideally $$R_0 = \frac{180}{2} = 90 \ \Omega$$

$$\% \text{ error} = \frac{R - R_0}{R_0} \times 100 = \frac{94.24 - 90 \times 100}{90} = 4.71\%$$

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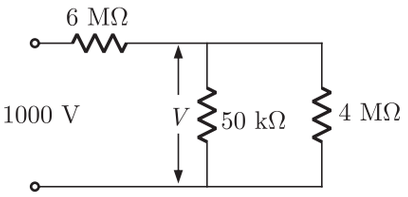
SOL 1.7.38 Option (A) is correct.

The measurement system is shown below



Voltmeter reading

$$V = \left(\frac{1000}{6\,\text{M}\Omega + 50\,\text{k}\Omega \parallel 4\,\text{M}\Omega}\right)(50\,\text{k}\Omega \parallel 4\,\text{M}\Omega)$$

$$= \frac{1000}{6 + .049} \times .049 = 8.10\ \text{V}$$

SOL 1.7.39 Option (D) is correct.

$$\text{Total power } P = P_1 + P_2 = 10.5 - 2.5 = 8\ \text{kW}$$

$$\text{Power factor} = \cos\theta$$

Where

$$\theta = \tan^{-1}\left[\sqrt{3}\left(\frac{P_2 - P_1}{P_2 + P_1}\right)\right] = \tan^{-1}\left[\sqrt{3} \times \frac{-13}{8}\right]$$

$$= -70.43^\circ$$

$$\text{Power factor} = \cos\theta = 0.334$$

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SOL 1.7.40 Option (B) is correct.

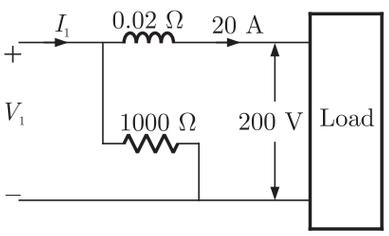
CHECK for the dc potentiometer $E \propto l$

so, $$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$E_2 = E_1\left(\frac{l_1}{l_2}\right) = (1.18) \times \frac{680}{600} = 1.34\ \text{V}$$

SOL 1.7.41 Option (C) is correct.

Let the actual voltage and current are I_1 and V_1 respectively, then



Current in CC is 20 A

$$20 = I_1\left(\frac{1000}{1000 + 0.02}\right)$$

$$I_1 = 20.0004\ \text{A} \simeq 20\ \text{A}$$

$$200 = V_1 - .02 \times 20 = 200.40$$

$$\text{Power measured } P_m = V_1 I_1 = 20(200.40) = 4008\ \text{W}$$

$$\text{Load power } P_L = 20 \times 200 = 4000\ \text{W}$$

$$\%\ \text{Change} = \frac{P_m - P_L}{P_L} = \frac{4008 - 4000}{4000} \times 100$$

$$= 0.2\%\ \text{more}$$

SOL 1.7.42 Option (C) is correct.

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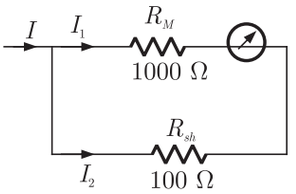
We have to obtain $n = \dfrac{I}{I_1}$



$$\frac{I_1}{I_2} = \frac{R_{sh}}{R_m} = \frac{100}{1000} = \frac{1}{10}$$

$$I_1 + I_2 = I$$

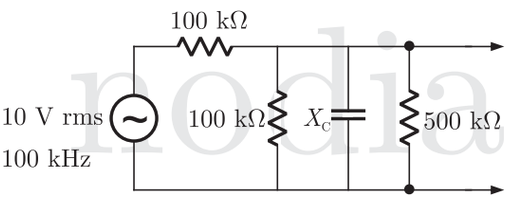
$$I_1 + 10I_1 = I$$

$$11I_1 = I$$

$$n = \frac{I}{I_1} = 11$$

SOL 1.7.43 Option (B) is correct.

In the following configuration



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Rectance $X_c = \dfrac{1}{j\omega C} = \dfrac{1}{2\pi \times 100 \times 10^3 \times 10 \times 10^{-12}}$

writing node equation at P

$$\frac{V_P - 10}{100} + V_P\left(\frac{1}{100} + \frac{1}{500} - \frac{j}{159}\right) = 0$$

$$10 - V_P = V_P(1.2 - j0.628)$$

$$10 = (2.2 - j0.628)\,V_P$$

$$V_P\ \frac{10}{2.28} = 4.38 \text{ V}$$

SOL 1.7.44 Option (A) is correct.

The torque on the coil is given by

$$\tau = NIBA$$

$N \rightarrow$ no. of turns, $\quad N = 100$

$I \rightarrow$ current, $\quad I = 50$ mA

$B \rightarrow$ magnetic field, $\quad B = 200$ mT $A \rightarrow$ Area,

$A = 10\,\text{mm} \times 20\,\text{mm}$

So, $\quad \tau = 100 \times 50 \times 10^{-3} \times 200 \times 10^{-3} \times 200 \times 10^{-3} \times 10^{-3}$

$= 200 \times 10^{-6}$ Nm

SOL 1.7.45 Option (C) is correct.

Meter constant (A-sec/rev) is given by

$$14.4 = \frac{\text{I}}{\text{speed}}$$

$$14.4 = \frac{\text{I}}{K \times \text{Power}}$$

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Where 'K' is the meter constant in rev/kWh.

$$14.4 = \frac{I}{K \times VI}$$

$$14.4 = \frac{15}{K \times 15 \times 250}$$

$$K = \frac{1}{250 \times 14.4}$$

$$K = \frac{1}{\left(\frac{250 \times 14.4}{1000 \times 3600}\right)} = \frac{1000 \times 3600}{3600} = 1000 \text{ rev/kWh.}$$

SOL 1.7.46 Option (B) is correct.

For moving iron ameter full scale torque is given by

$$\tau_C = \frac{1}{2} I^2 \frac{dL}{d\theta}$$

$$240 \times 10^{-6} = \frac{1}{2}(10)^2 \frac{dL}{d\theta}$$

Change in inductance

$$\frac{dL}{d\theta} = 4.8 \ \mu\text{H/radian}$$

SOL 1.7.47 Option (B) is correct.

In the figure

$$V_{RY} = 415\angle 30^\circ$$

$$V_{BN} = \frac{415}{\sqrt{3}}\angle 120^\circ$$

Current in current coil

$$I_C = \frac{V_{RY}}{Z} = \frac{415\angle 30^\circ}{100\angle 36.87^\circ} = 4.15\angle -6.87$$

$\therefore$ power factor $= 0.8$

$\cos\phi = 0.8 \Rightarrow \phi = 36.87^\circ$

$$\text{Power} = VI^* = \frac{415}{\sqrt{3}}\angle 120^\circ \times 4.15\angle 6.87^\circ$$

$$= 994.3\angle 126.87^\circ$$

Reading of wattmeter

$$P = 994.3(\cos 126.87^\circ) = 994.3(-0.60) = -597 \text{ W}$$

SOL 1.7.48 Option (A) is correct.

For small values of phase angle

$$\frac{I_P}{I_S} = n\phi, \quad \phi \rightarrow \text{Phase angle (radians)}$$

$$\text{n} \rightarrow \text{turns ratio}$$

Magnetizing ampere-turns $= 200$

So primary current $I_P = 200 \times 1 = 200$ amp

Turns ratio $n = 500$

Secondary current $I_S = 5$ amp

So $$\frac{200}{5} = 500\phi$$

$$\phi \text{ (in degrees)} = \left(\frac{180}{\pi}\right)\left(\frac{200}{5 \times 500}\right)$$

$$\simeq 4.58^\circ$$

SOL 1.7.49 Option (B) is correct.

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Voltage appeared at secondary winding

$$E_S = I_S \times Z_L = 5 \times 1 = 5 \text{ Volts}$$

Voltage induced is given by

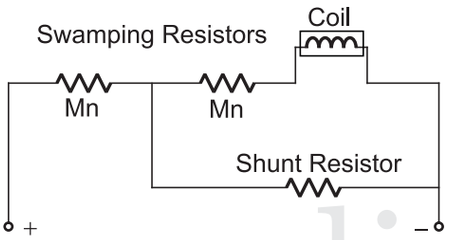
$$E_S = \sqrt{2}\,\pi f N \phi, \quad \phi \rightarrow \text{flux}$$

$$5 = \sqrt{2} \times 3.14 \times 50 \times 500 \times \phi$$

$$\phi = \frac{5}{\sqrt{2} \times 3.14 \times 25 \times 10^3} = 45 \times 10^{-6} \text{ wb}$$

SOL 1.7.50 Option (A) is correct.

In PMCC instruments, as temperature increases the coil resistance increases. Swamp resistors are connected in series with the moving coil to provide temperature compensation. Swamping resistors is made of magnin, which has a zero-temperature coefficient.



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SOL 1.7.51 Option () is correct.

Effect of stray magnetic field is maximum when the operating field and stray fields are parallel.

SOL 1.7.52 Option (A) is correct.

Let $C_1 = 300$ pF

$$Q = 120 = \frac{1}{\omega C_1 R}$$

Now when C_x is connected in parallel with variable resistor $C_1' = 200$ pF

$$Q = 120 = \frac{1}{\omega (C_1' + C_x) R}$$

So $C_1 = C_1' + C_x$

$$300 = 200 + C_x$$

$$C_x = 100 \text{ pF}$$

SOL 1.7.53 Option (B) is correct.

Maximum frequency of input in dual slop A/D converter is given as

$$T_m = 2^n T_C$$

where $f_m = \frac{1}{T_m} \rightarrow$ maximum frquency of input

$$f_C = \frac{1}{T_C} \rightarrow \text{clock frequency}$$

so $f_m = \frac{f_C}{2^n}, \quad n = 10$

$$= \frac{10^6}{1024} = 1 \text{ kHz (approax)}$$

SOL 1.7.54 Option (A) is correct.

Kelvin Double bridge is used for measuring low values of resistances. (P → 2)

Low values of capacitances is precisely measured by schering bridge (Q → 3)

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Inductance of a coil with large time constant or high quality factor is measured by hay's bridge ($R \to 5$)

SOL 1.7.55 Option (C) is correct.

Full scale deflection is produced by a dc current of 1 mA

$$(I_{dc})_{fs} = 1 \text{ mA}$$

For full wave reactifier

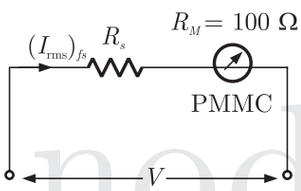
$$(I_{dc})_{fs} = \frac{2I_m}{\pi}, \quad I_m \to \text{peak value of ac current}$$

$$1 \text{ mA} = \frac{2I_m}{3.14}$$

$$I_m = 1.57 \text{ mA}$$

Full scale ac current

$$(I_{rms})_{fs} = \frac{1.57}{\sqrt{2}} = 1.11 \text{ mA}$$



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$$V = (R_s + R_m)(I_{rms})_{fs}$$

$$100 = (R_s + 100)(1.11 \text{ mA})$$

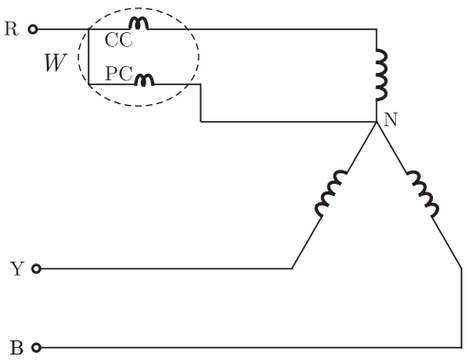
$$\frac{100}{(1.11 \text{ mA})} = R_s + 100$$

$$100 \times 900 = R_s + 100$$

$$R_s = 89.9 \text{ k}\Omega$$

SOL 1.7.56 Option (B) is correct.

First the current coil is connected in R-phase and pressure coil is connected between this phase and the neutral as shown below



reading of wattmeter

$$W_1 = I_P V_P \cos\theta_1, \ \cos\theta_1 = 0.8 \Rightarrow \theta_1 = 36.86^\circ$$

$$400 = I_L \frac{V_L}{\sqrt{3}} \cos\theta_1$$

$$400 = \frac{I_L V_L}{\sqrt{3}} \times 0.8 \qquad \ldots(1)$$

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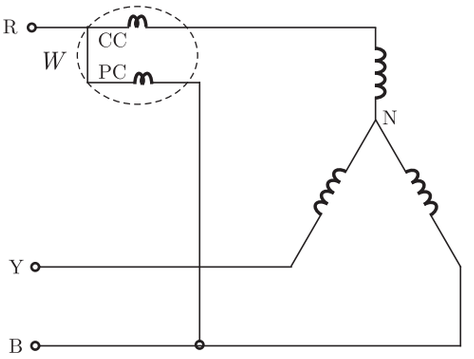
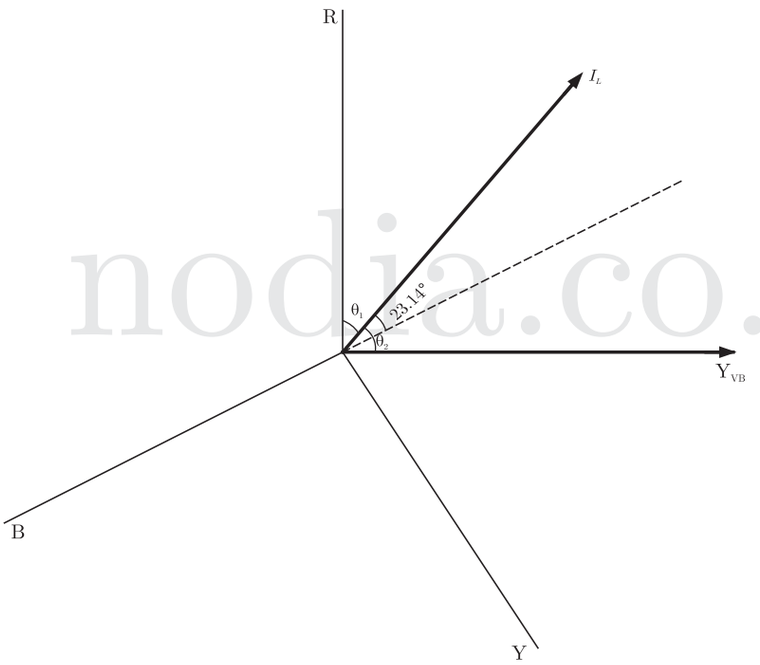
Now when pressure coil is connected between B and Y-phases, the circuit is



phasor diagram



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angle $\theta_2 = 23.14^\circ + 30^\circ = 54.14^\circ 2$

now wattmeter reading $W_2 = V_{YB} I_L \cos\theta_2$

from equation (1) $V_L I_L = \dfrac{400 \times \sqrt{3}}{0.8}$

so $W_2 = \dfrac{400}{0.8} \times \sqrt{3} \times \cos 53.14^\circ$

$= 519.5 \text{ W}$

SOL 1.7.57 Option (C) is correct.

In a moving-iron ammeter control torque is given as

$$\tau_c = K\theta = \frac{1}{2} I^2 \frac{dL}{d\theta}$$

Where

$K \rightarrow$ control spring constant

$\theta \rightarrow$ deflection

Given that $L = 10 + 3\theta - \dfrac{\theta^2}{4}$

$$\frac{dL}{d\theta} = \left(3 - \frac{\theta}{2}\right) \mu\text{H/rad}$$

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So,

$$\tau_c = (25 \times 10^{-6})\theta = \frac{1}{2}(5)^2\left(3 - \frac{\theta}{2}\right) \times 10^{-6}$$

$$2\theta = 3 - \frac{\theta}{2}$$

$$\frac{5\theta}{2} = 3 \Rightarrow \theta = \frac{6}{5} = 1.2 \text{ rad.}$$

SOL 1.7.58 Option (B) is correct.

$$\text{Magnetizing current } I_m = \frac{250}{1} = 250 \text{ amp}$$

$$\text{Primary current } I_p = 500 \text{ amp}$$

$$\text{Secondary current } I_s = 5 \text{ amp}$$

$$\text{Turn ratio } n = \frac{I_p}{I_s} = \frac{500}{5} = 100$$

$$\text{Total primary current } (I_T) = \sqrt{[\text{primary current } (I_p)]^2} + \sqrt{[\text{magnetising current } (I_m)]^2}$$

$$I_T = \sqrt{I_p^2 + I_m^2}$$

$$= \sqrt{(500)^2 + (250)^2} = 559.01 \text{ amp}$$

$$\text{Turn ratio } n' = \frac{I_T}{I_s} = \frac{559.01}{5} = 111.80$$

$$\text{Percentage ratio error } \Delta n = \frac{n - n'}{n'} \times 100$$

$$= \frac{100 - 111.80}{111.80} \times 100 = -10.55\%$$

SOL 1.7.59 Option (C) is correct.

Power read by meter $P_m = VI\sin(\Delta - \phi)$

Where

$\Delta \rightarrow$Phase angle between supply voltage and pressure coil flux.

$\phi \rightarrow$Phase angle of load

Here

$\Delta = 85^\circ, \phi = 60^\circ \quad \{\because \cos\phi = 0.5$

So measured power

$$P_m = 200 \times 5\sin(85^\circ - 60^\circ)$$

$$= 1100\sin 25^\circ$$

$$= 464.88 \text{ W}$$

Actual power $P_O = VI\cos\phi = 220 \times 5 \times 0.5 = 550$ W

Error in measurement $= P_m - P_O = 464.88 - 550 = -85.12$ W

For unity power factor $\cos\phi = 1$

$$\phi = 0^\circ$$

So $P_m = 220 \times 5\sin(85^\circ - 0^\circ) = 1095.81$ W

$P_O = 220 \times 5\cos 0^\circ = 1100$

Error in Measurement

$$= 1095.81 - 1100 = -4.19 \text{ W}$$

SOL 1.7.60 Option (A) is correct.

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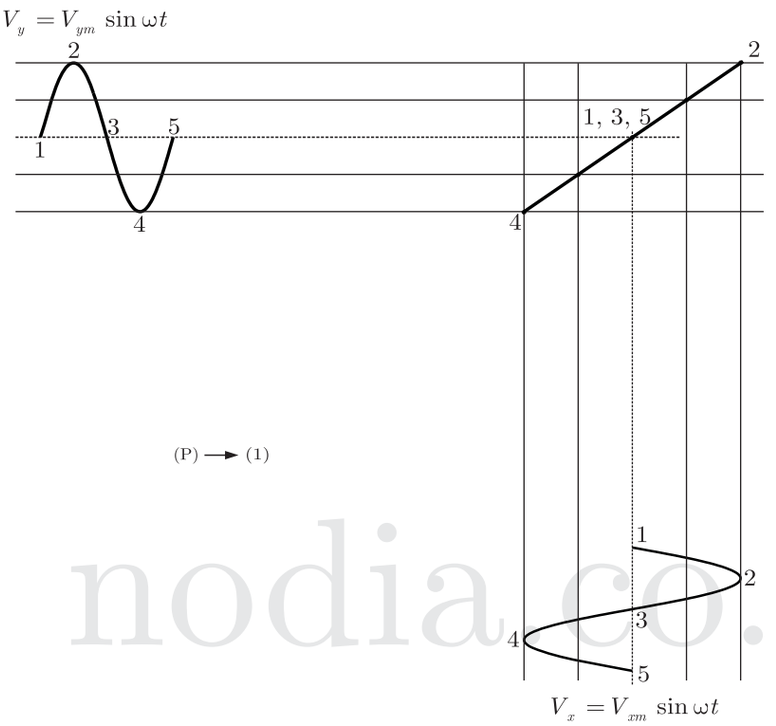
We can obtain the Lissaju pattern (in X-Y mode) by following method.

For $\phi = 0^\circ$, $V_x = V_{xm}\sin\omega t$

$V_y = V_{ym}\sin(\omega t + 0^\circ) = \sin\omega t$

Draw V_x and V_y as shown below



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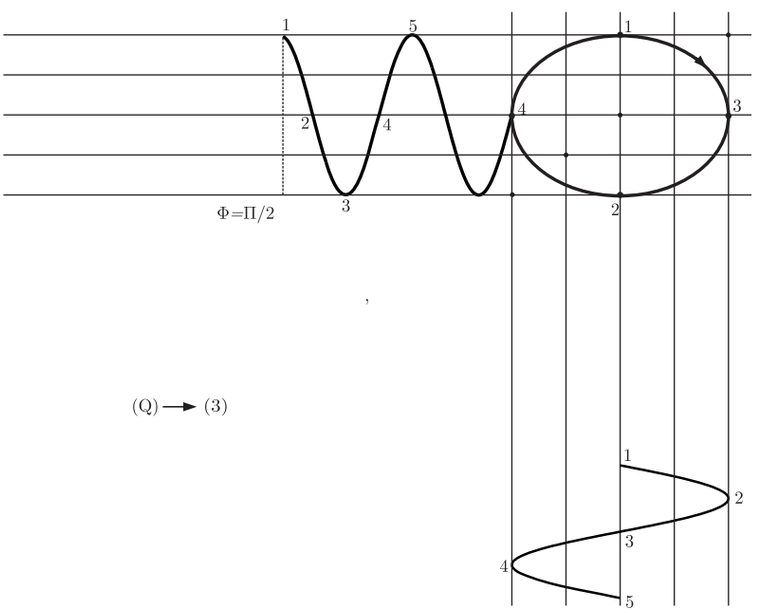
Divide both V_y and V_x equal parts and match the corresponding points on the screen.

Similarly for $\phi = 90^\circ$

$V_x = V_{xm}\sin\omega t$

$V_y = V_{ym}\sin(\omega t + 90^\circ)$



Similarly for $\phi = \dfrac{3\pi}{2}$

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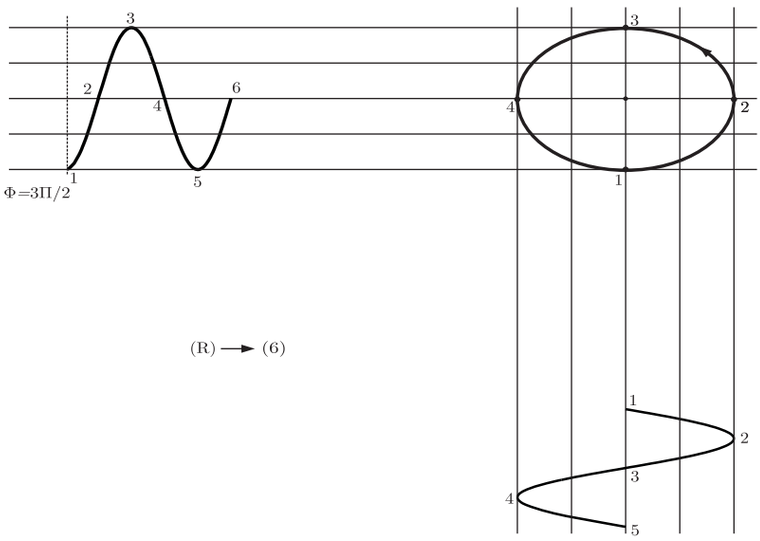
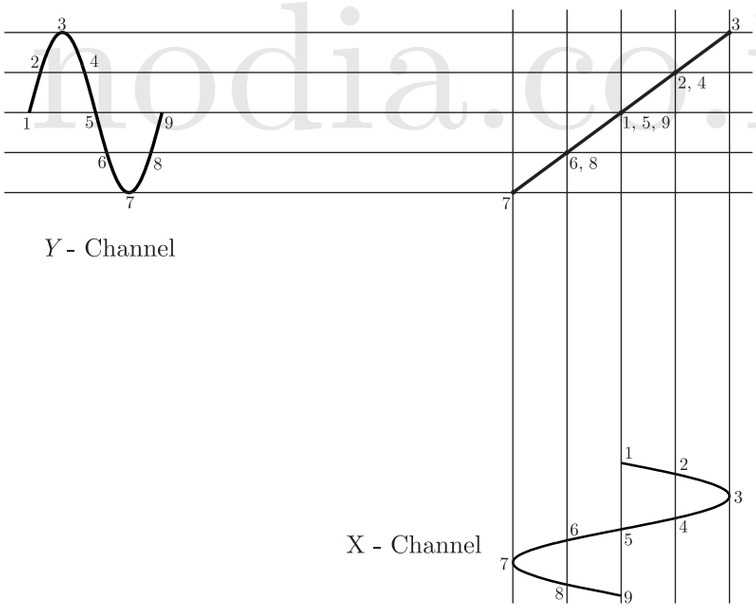


we can also obtain for $0 < \phi < \dfrac{3\pi}{2}$

SOL 1.7.61 Option (D) is correct.

We can obtain the Lissaju pattern (in X-Y made) by following method.



Divide the wave forms appearing an channel X and channel Y in equal parts, match the corresponding points on the screen. We would get a straight line in $X - Y$ mode.

SOL 1.7.62 Option (C) is correct.

In two wattmeters method angle between phase voltage and phase current is given by

$$\phi = \tan^{-1}\left(\sqrt{3}\frac{W_2 - W_1}{W_2 + W_1}\right)$$

here $\phi = -60^\circ$

readings in option (C) only satisfies this equation.

$$\phi = \tan^{-1}\left(\sqrt{3}\frac{0 - 1000}{0 + 1000}\right) = -60^\circ$$

SOL 1.7.63 Option (D) is correct.

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Speed (rev/sec) of the energy meter is given.

$$S = K \times \text{power}$$

$K \rightarrow$ meter constant

$$S = \frac{10\,rev}{100\,\text{sec}} = K \times 450$$

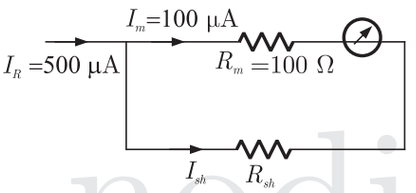
$$K = \frac{10 \text{ rev}}{\left(\frac{100 \times 450}{1000 \times 3600}\right) \text{kWh}} = \frac{10 \times 1000 \times 3600}{100 \times 450}$$
$$= 800 \text{ rev/kWh}$$

SOL 1.7.64 Option (B) is correct.

Power in a 3-phase three wire system, with balanced load can be measured by using two wattmeters. The load may be star or delta connected.

SOL 1.7.65 Option (C) is correct.

Ameter configuration is given below



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Here
$$I_R = I_m + I_{sh}$$
$$500 = 100 + I_{sh}$$
$$I_{sn} = 400 \text{ μA}$$
$$\frac{I_m}{I_{sh}} = \frac{R_{sh}}{R_m}$$
$$\frac{100}{400} = \frac{R_{sh}}{100}$$
$$R_{sh} = 25\,\Omega$$

SOL 1.7.66 Option (A) is correct.

Equivalent resistance when connected in parallel is

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

Let $R_1 + R_2 = R_{\text{sum}}$

So $$R = \frac{R_1 R_2}{R_{\text{sum}}} = \frac{10 \times 5}{15} = 3.33\,\Omega$$

$$\%\text{ error in } R = \Delta R_1(\%) + \Delta R_2(\%) - \Delta R_{\text{sum}}(\%)$$
$$\Delta R_{\text{sum}} = (10 \pm 5\%) + (5 \pm 10\%)$$
$$= (10 \pm 0.5) + (5 \pm 0.5) = 15 \pm 0.1$$
$$\Delta R_{\text{sum}}(\%) = 15 \pm \frac{1}{15} \times 100\% = 15 \pm 6.66\%$$
$$\%\text{ error in } R = 5\% + 10\% - 6.66\% = 8.33\%$$
$$\text{value of } R = 3.33 \pm 8.33\% = 3.05\,\Omega \text{ to } 3.61\,\Omega$$

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8

ANALOG & DIGITAL ELECTRONICS

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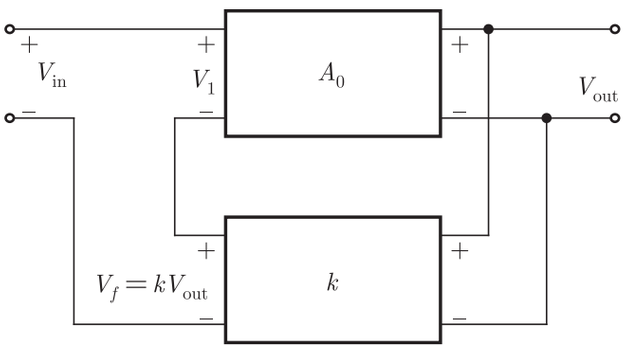
MCQ 1.8.1 A bulb in a staircase has two switches, one switch being at the ground floor and the other one at the first floor. The bulb can be turned ON and also can be turned OFF by any one of the switches irrespective of the state of the other switch. The logic of switching of the bulb resembles

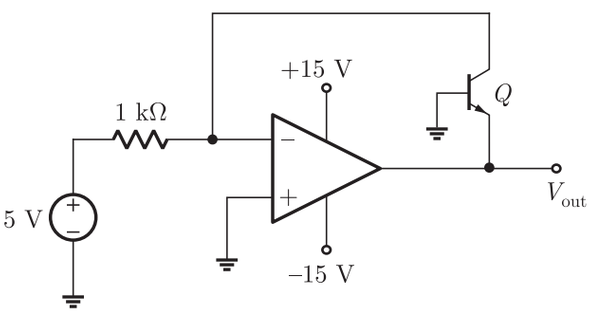
(A) and AND gate
(B) an OR gate
(C) an XOR gate
(D) a NAND gate

MCQ 1.8.2 In a voltage-voltage feedback as shown below, which one of the following statements is TRUE if the gain k is increased?



(A) The input impedance increases and output impedance decreases
(B) The input impedance increases and output impedance also increases
(C) The input impedance decreases and output impedance also decreases
(D) The input impedance decreases and output impedance increases

MCQ 1.8.3 In the circuit shown below what is the output voltage (V_{out}) if a silicon transistor Q and an ideal op-amp are used?



(A) -15 V
(B) -0.7 V
(C) $+0.7$ V
(D) $+15$ V

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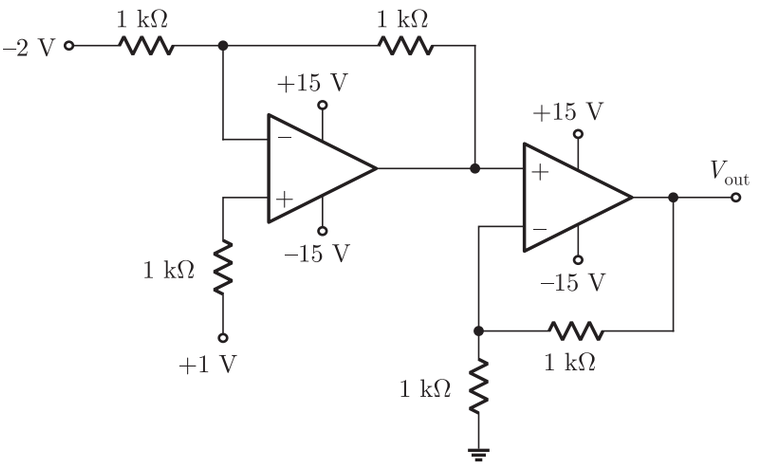
MCQ 1.8.4 In the circuit shown below the op-amps are ideal. Then, V_{out} in Volts is



(A) 4 (B) 6

(C) 8 (D) 10

MCQ 1.8.5 In the circuit shown below, Q_1 has negligible collector-to-emitter saturation voltage and the diode drops negligible voltage across it under forward bias. If V_{cc} is $+5\,\text{V}$, X and Y are digital signals with $0\,\text{V}$ as logic 0 and V_{cc} as logic 1, then the Boolean expression for Z is

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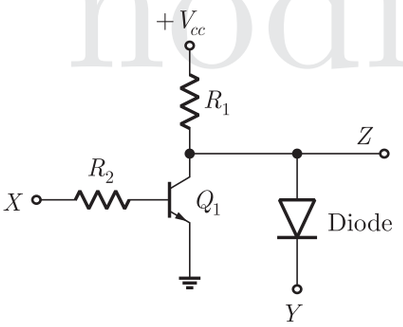
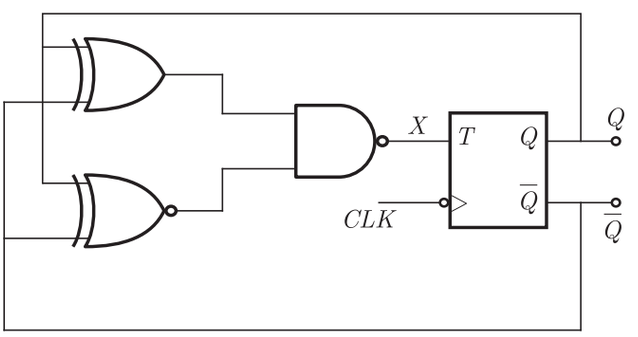


(A) XY (B) $\overline{X}Y$

(C) $X\overline{Y}$ (D) $\overline{XY}$

MCQ 1.8.6 The clock frequency applied to the digital circuit shown in the figure below is $1\,\text{kHz}$. If the initial state of the output of the flip-flop is 0, then the frequency of the output waveform Q in kHz is



(A) 0.25 (B) 0.5

(C) 1 (D) 2

MCQ 1.8.7 A voltage $1000\sin\omega t$ Volts is applied across YZ. Assuming ideal diodes, the voltage measured across WX in Volts, is

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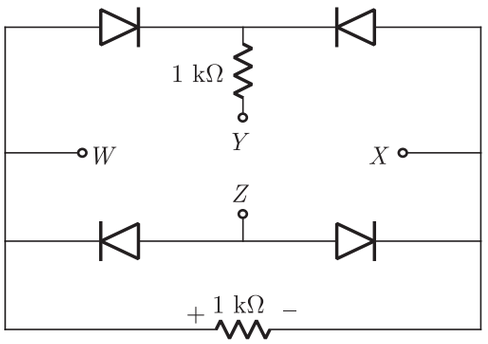
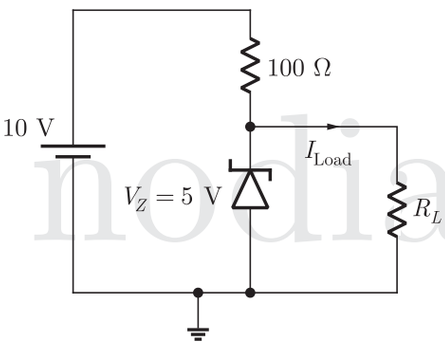


(A) $\sin\omega t$
(B) $\left(\sin\omega t + \left|\sin\omega t\right|\right)/2$
(C) $\left(\sin\omega t - \left|\sin\omega t\right|\right)/2$
(D) 0 for all t

MCQ 1.8.8 In the circuit shown below, the knee current of the ideal Zener dioide is 10 mA . To maintain 5 V across R_L, the minimum value of R_L in Ω and the minimum power rating of the Zener diode in mW, respectively, are



(A) 125 and 125
(B) 125 and 250
(C) 250 and 125
(D) 250 and 250

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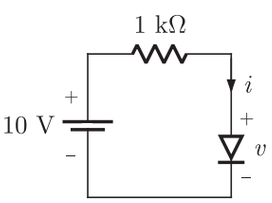
MCQ 1.8.9 In the sum of products function $f(X,Y,Z) = \sum(2,3,4,5)$, the prime implicants are

(A) $\overline{X}Y$, $X\overline{Y}$
(B) $\overline{X}Y$, $X\,\overline{Y}\,\overline{Z}$, $X\overline{Y}Z$
(C) $\overline{X}Y\overline{Z}$, $\overline{X}YZ$, $X\overline{Y}$
(D) $\overline{X}Y\overline{Z}$, $\overline{X}YZ$, $X\overline{Y}\,\overline{Z}$, $X\overline{Y}Z$

MCQ 1.8.10 The i-v characteristics of the diode in the circuit given below are

$$i = \begin{cases} \dfrac{v - 0.7}{500}\ \text{A}, & v \geq 0.7\ \text{V} \\ 0\ \text{A} & v < 0.7\ \text{V} \end{cases}$$



The current in the circuit is

(A) 10 mA
(B) 9.3 mA
(C) 6.67 mA
(D) 6.2 mA

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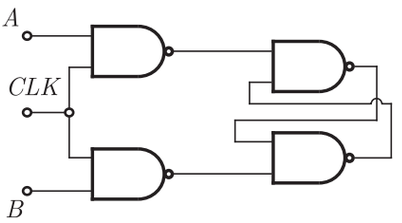
MCQ 1.8.11 The output Y of a 2-bit comparator is logic 1 whenever the 2-bit input A is greater than the 2-bit input B. The number of combinations for which the output is logic 1, is

(A) 4 (B) 6

(C) 8 (D) 10

MCQ 1.8.12 Consider the given circuit



In this circuit, the race around

(A) does not occur

(B) occur when $CLK = 0$

(C) occur when $CLK = 1$ and $A = B = 1$

(D) occur when $CLK = 1$ and $A = B = 0$

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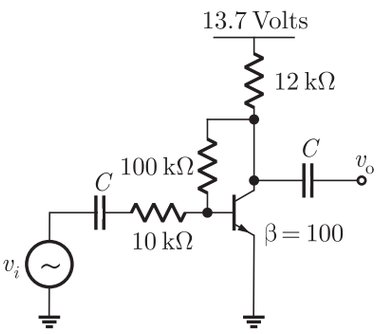
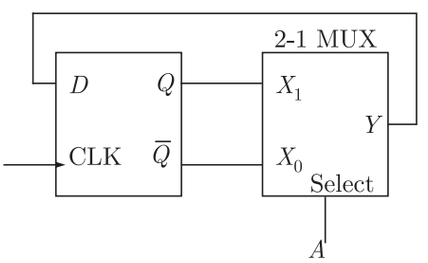
MCQ 1.8.13 The voltage gain A_v of the circuit shown below is



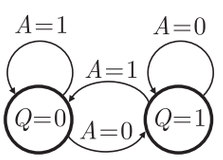
(A) $|A_v| \approx 200$ (B) $|A_v| \approx 100$

(C) $|A_v| \approx 20$ (D) $|A_v| \approx 10$

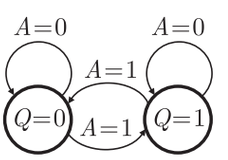
MCQ 1.8.14 The state transition diagram for the logic circuit shown is



(A)



(B)



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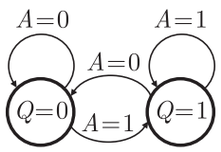
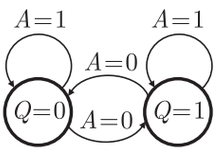
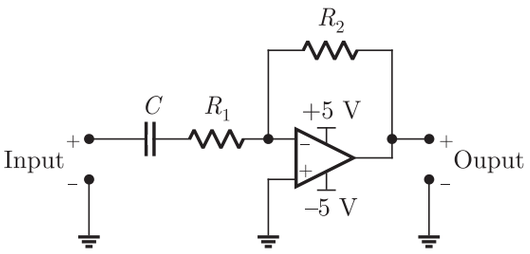
(C)



(B)



MCQ 1.8.15 The circuit shown is a



(A) low pass filter with $f_{3dB} = \dfrac{1}{(R_1 + R_2)C}$ rad/s

(B) high pass filter with $f_{3dB} = \dfrac{1}{R_1 C}$ rad/s

(C) low pass filter with $f_{3dB} = \dfrac{1}{R_1 C}$ rad/s

(D) high pass filter with $f_{3dB} = \dfrac{1}{(R_1 + R_2)C}$ rad/s

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MCQ 1.8.16 A low-pass filter with a cut-off frequency of 30 Hz is cascaded with a high pass filter with a cut-off frequency of 20 Hz. The resultant system of filters will function as

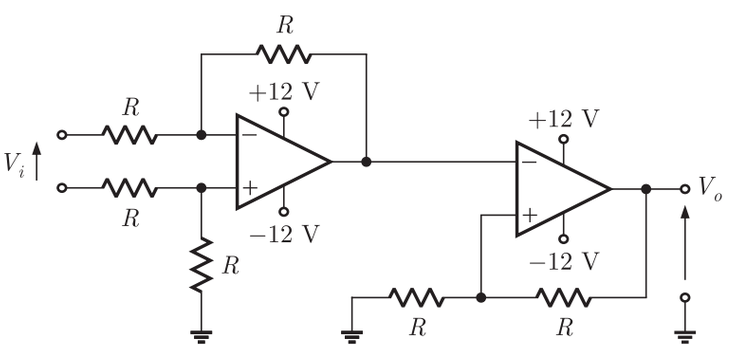
(A) an all – pass filter

(B) an all – stop filter

(C) an band stop (band-reject) filter

(D) a band – pass filter

MCQ 1.8.17



The CORRECT transfer characteristic is

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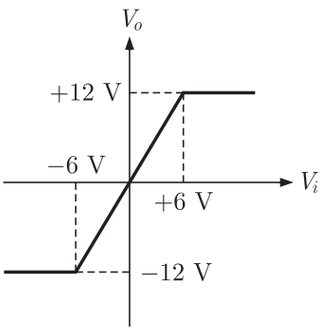
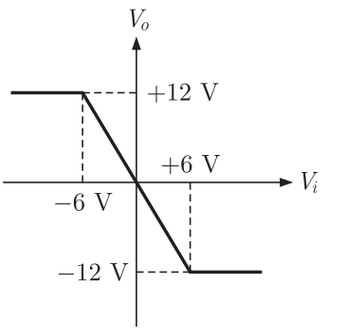
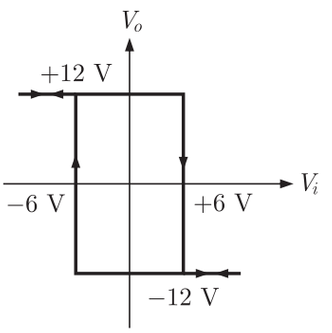
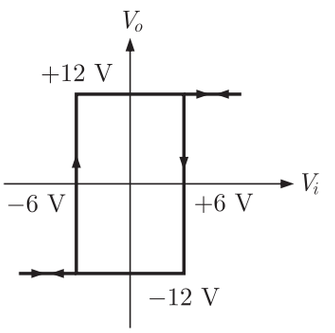
(A)


(B)


(C)


(D)


MCQ 1.8.18 The output Y of the logic circuit given below is

(A) 1
(B) 0
(C) X
(D) $\overline{X}$

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MCQ 1.8.19 A portion of the main program to call a subroutine SUB in an 8085 environment is given below.

⋮
LXI D, DISP
LP : CALL SUB
LP+3
⋮

It is desired that control be returned to LP+DISP+3 when the RET instruction is executed in the subroutine. The set of instructions that precede the RET instruction in the subroutine are

(A)
```
POP  D
DAD  H
PUSH D
```

(B)
```
POP  H
DAD  D
INX  H
INX  H
INX  H
PUSH H
```

(C)
```
POP  H
DAD  D
PUSH H
```

(D)
```
XTHL
INX  D
INX  D
INX  D
XTHL
```

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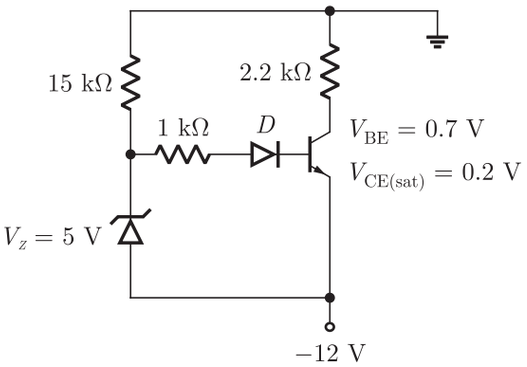
MCQ 1.8.20 The transistor used in the circuit shown below has a β of 30 and I_{CBO} is negligible

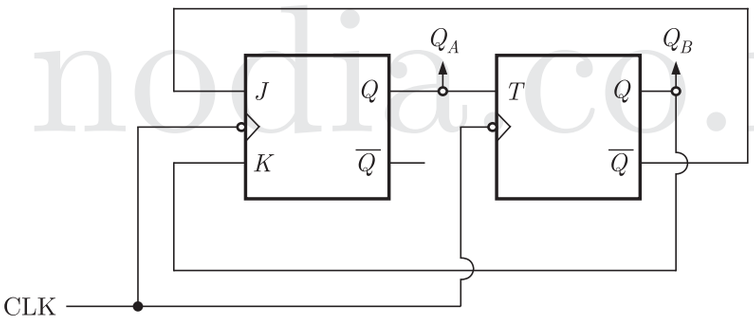


If the forward voltage drop of diode is 0.7 V, then the current through collector will be

(A) 168 mA (B) 108 mA

(C) 20.54 mA (D) 5.36 mA

MCQ 1.8.21 A two bit counter circuit is shown below

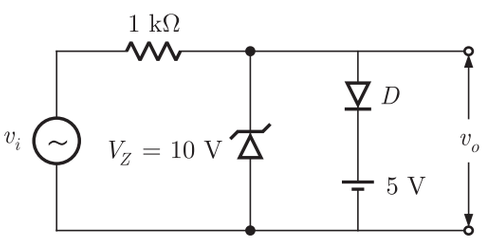


It the state Q_AQ_B of the counter at the clock time t_n is '10' then the state Q_AQ_B of the counter at $t_n + 3$ (after three clock cycles) will be

(A) 00 (B) 01

(C) 10 (D) 11

MCQ 1.8.22 A clipper circuit is shown below.



Assuming forward voltage drops of the diodes to be 0.7 V, the input-output transfer characteristics of the circuit is

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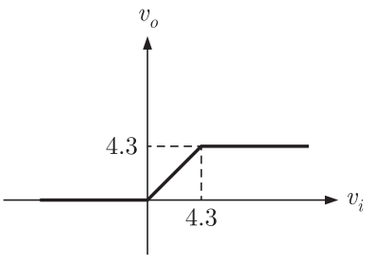
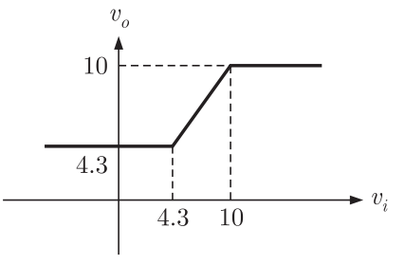
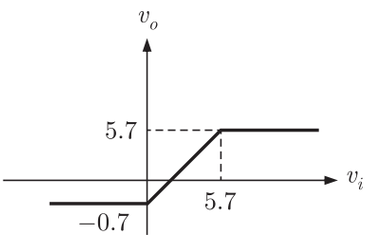
(A)



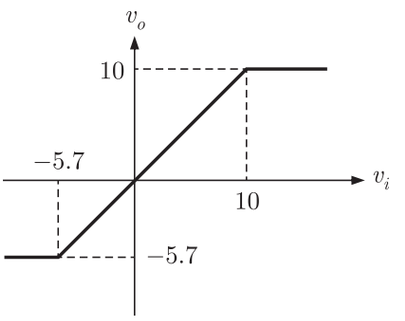
(B)



(C)



(D)



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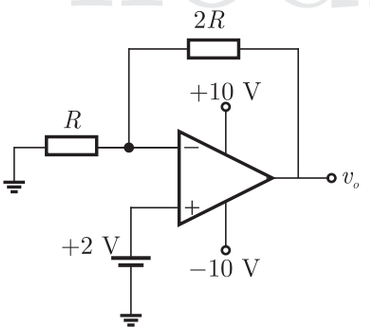
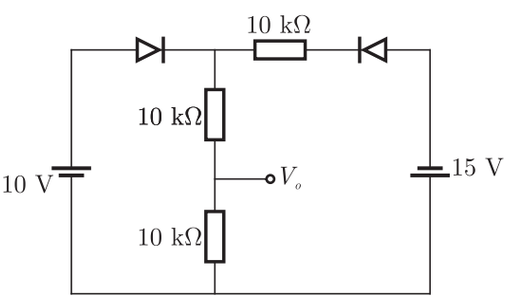
MCQ 1.8.23 Given that the op-amp is ideal, the output voltage v_o is



(A) 4 V (B) 6 V

(C) 7.5 V (D) 12.12 V

MCQ 1.8.24 Assuming that the diodes in the given circuit are ideal, the voltage V_0 is



(A) 4 V (B) 5 V

(C) 7.5 V (D) 12.12 V

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MCQ 1.8.25 The transistor circuit shown uses a silicon transistor with $V_{BE} = 0.7, I_C \approx I_E$ and

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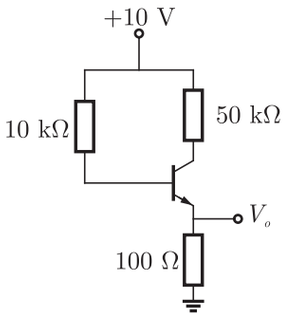
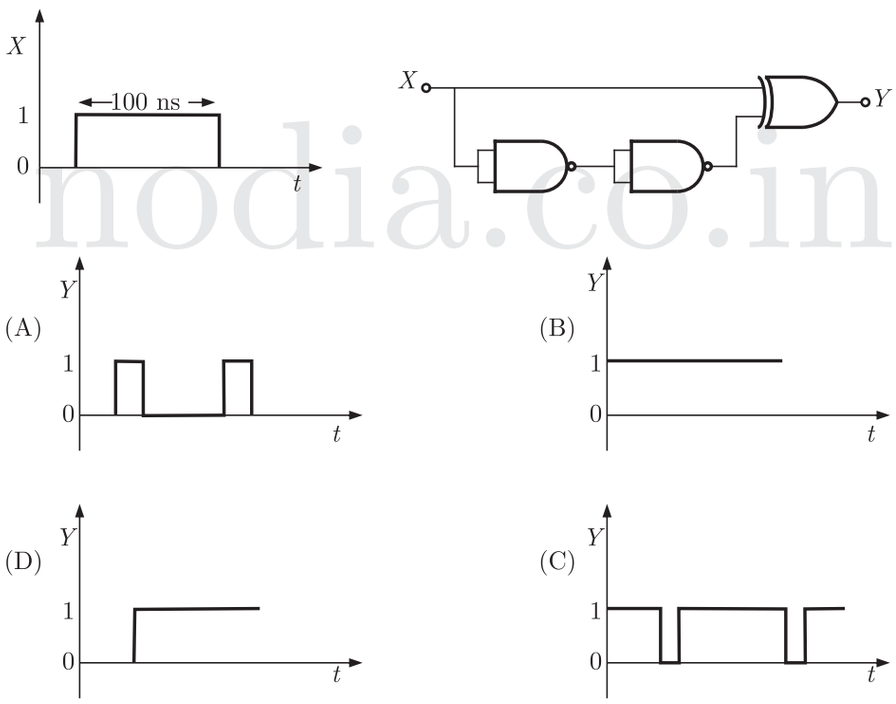
a dc current gain of 100. The value of V_0 is



(A) 4.65 V (B) 5 V

(C) 6.3 V (D) 7.23 V

MCQ 1.8.26 The TTL circuit shown in the figure is fed with the waveform X (also shown). All gates have equal propagation delay of 10 ns. The output Y of the circuit is



MCQ 1.8.27 When a "CALL Addr" instruction is executed, the CPU carries out the following sequential operations internally :

Note: (R) means content of register R
((R)) means content of memory location pointed to by R.
PC means Program Counter
SP means Stack Pointer

(A) (SP) incremented
(PC)←Addr
((SP))←(PC)

(B) (PC)←Addr
((SP))←(PC)
(SP) incremented

(C) (PC)←Addr
(SP) incremented
((SP))←(PC)

(D) ((SP))←(PC)
(SP) incremented
(PC)←Addr

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Statement For Linked Answer Questions: 28 & 29

The following Karnaugh map represents a function F.

F / X \ YZ	00	01	11	10
0	1	1	1	0
1	0	0	1	0

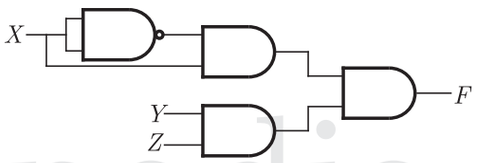
MCQ 1.8.28 A minimized form of the function F is

(A) $F = \overline{X}\,Y + YZ$ (B) $F = \overline{X}\,\overline{Y} + YZ$

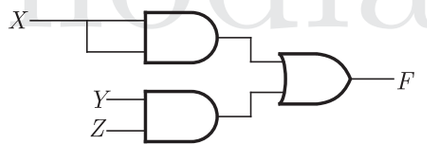
(C) $F = \overline{X}\,\overline{Y} + Y\,\overline{Z}$ (D) $F = \overline{X}\,\overline{Y} + \overline{Y}\,Z$

MCQ 1.8.29 Which of the following circuits is a realization of the above function F ?

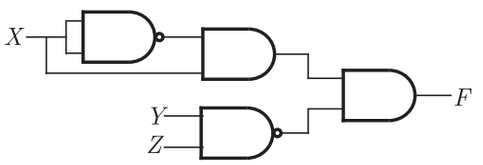
(A)



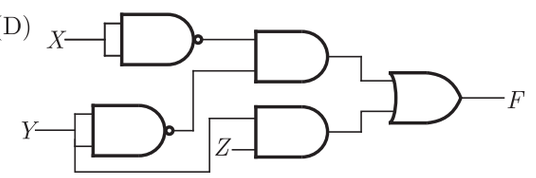
(B)



(C)



(D)



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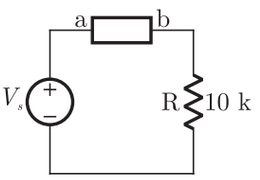
MCQ 1.8.30 The following circuit has a source voltage V_S as shown in the graph. The current through the circuit is also shown.



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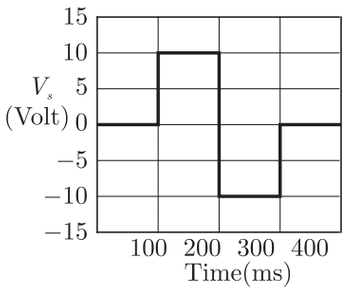
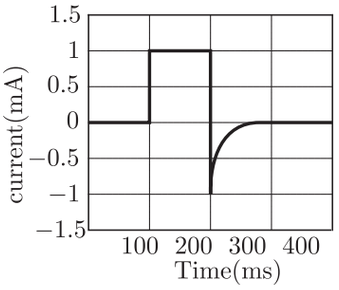
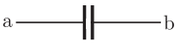




The element connected between a and b could be

(A)

(B)



(C)

(D)

MCQ 1.8.31 The increasing order of speed of data access for the following device is

(I) Cache Memory

(II) CD-ROM

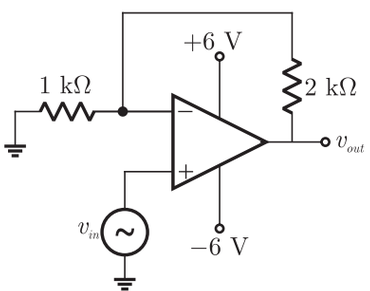
(III) Dynamic RAM

(IV) Processor Registers

(V) Magnetic Tape

(A) (V), (II), (III), (IV), (I)
(B) (V), (II), (III), (I), (IV)
(C) (II), (I), (III), (IV), (V)
(D) (V), (II), (I), (III), (IV)

MCQ 1.8.32 The nature of feedback in the op-amp circuit shown is



(A) Current-Current feedback
(B) Voltage-Voltage feedback
(C) Current-Voltage feedback
(D) Voltage-Current feedback

MCQ 1.8.33 The complete set of only those Logic Gates designated as Universal Gates is

(A) NOT, OR and AND Gates

(B) XNOR, NOR and NAND Gates

(C) NOR and NAND Gates

(D) XOR, NOR and NAND Gates

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MCQ 1.8.34 The following circuit has $R = 10\,\text{k}\Omega, C = 10\,\mu\text{F}$. The input voltage is a sinusoidal at 50 Hz with an rms value of 10 V. Under ideal conditions, the current I_s from

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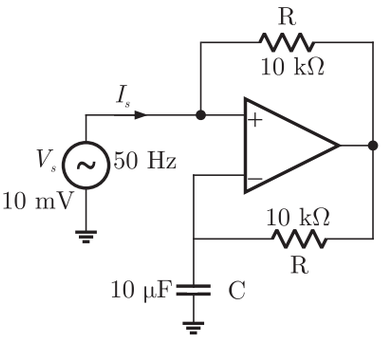
the source is



(A) 10π mA leading by 90° (B) 20π mA leading by 90°

(C) 10π mA leading by 90° (D) 10π mA lagging by 90°

MCQ 1.8.35 Transformer and emitter follower can both be used for impedance matching at the output of an audio amplifier. The basic relationship between the input power P_{in} and output power P_{out} in both the cases is

(A) $P_{in} = P_{out}$ for both transformer and emitter follower

(B) $P_{in} > P_{out}$ for both transformer and emitter follower

(C) $P_{in} < P_{out}$ for transformer and $P_{in} = P_{out}$ for emitter follower

(D) $P_{in} = P_{out}$ for transformer and $P_{in} < P_{out}$ for emitter follower

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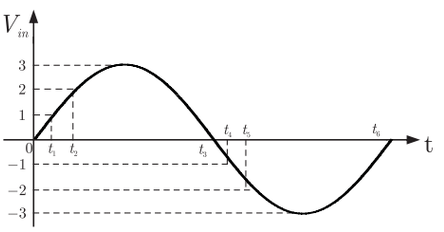
MCQ 1.8.36 In an 8085 microprocessor, the contents of the Accumulator, after the following instructions are executed will become

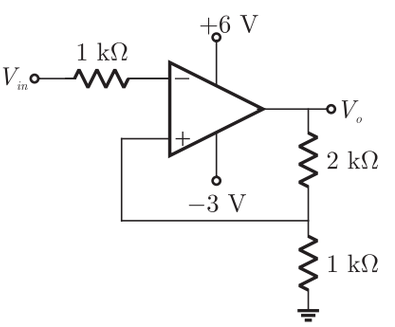
```
XRA  A
MVI  B, F0 H
SUB  B
```

(A) 01 H (B) 0F H

(C) F0 H (D) 10 H

MCQ 1.8.37 An ideal op-amp circuit and its input wave form as shown in the figures. The output waveform of this circuit will be





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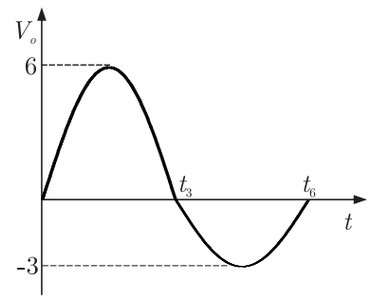
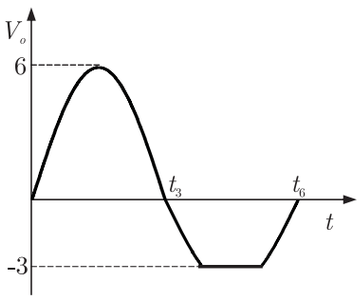
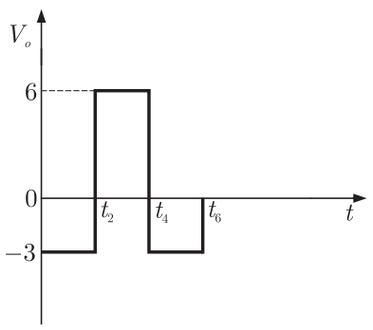
(A)



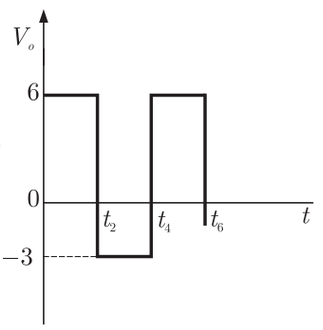
(B)



(C)



(D)



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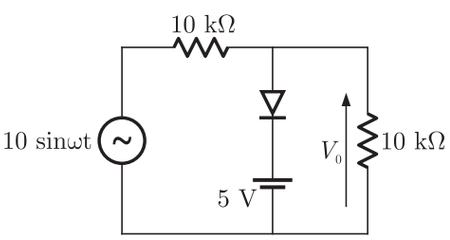
MCQ 1.8.38 The equivalent circuits of a diode, during forward biased and reverse biased conditions, are shown in the figure.

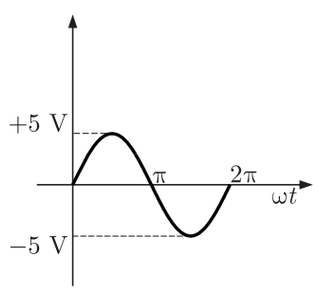
(I)

(II)

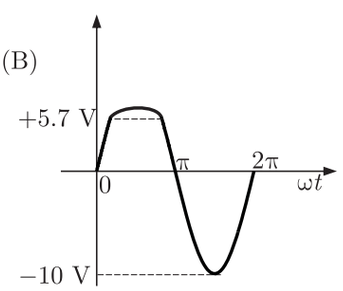


If such a diode is used in clipper circuit of figure given above, the output voltage V_0 of the circuit will be

(A)



(B)



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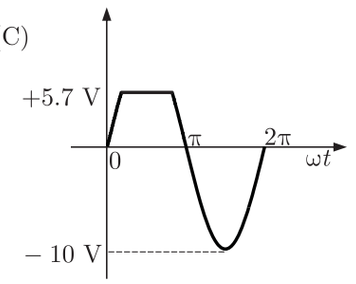
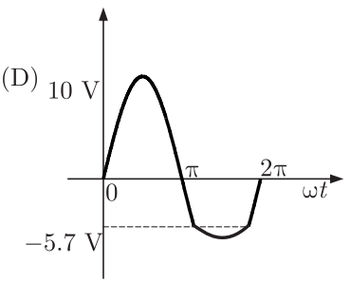
(C)



(D)



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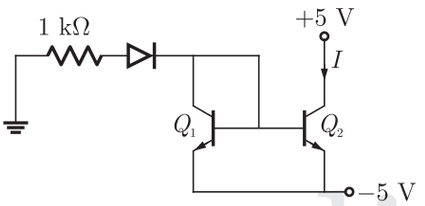
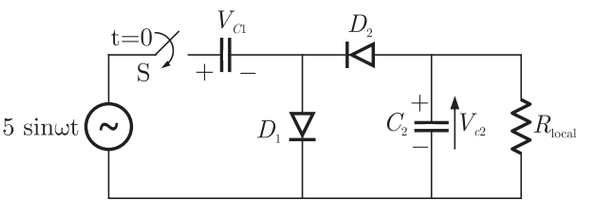
MCQ 1.8.39 Two perfectly matched silicon transistor are connected as shown in the figure assuming the β of the transistors to be very high and the forward voltage drop in diodes to be 0.7 V, the value of current I is



(A) 0 mA (B) 3.6 mA

(C) 4.3 mA (D) 5.7 mA

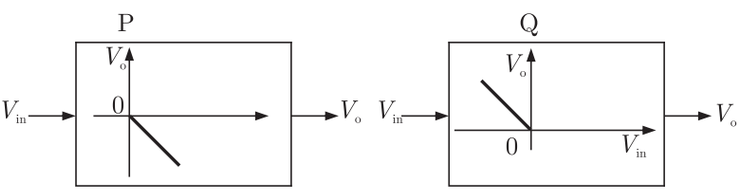
MCQ 1.8.40 In the voltage doubler circuit shown in the figure, the switch 'S' is closed at $t = 0$. Assuming diodes D_1 and D_2 to be ideal, load resistance to be infinite and initial capacitor voltages to be zero. The steady state voltage across capacitor C_1 and C_2 will be



(A) $V_{c1} = 10$ V, $V_{c2} = 5$ V (B) $V_{c1} = 10$ V, $V_{c2} = -5$ V

(C) $V_{c1} = 5$ V, $V_{c2} = 10$ V (D) $V_{c1} = 5$ V, $V_{c2} = -10$ V

MCQ 1.8.41 The block diagrams of two of half wave rectifiers are shown in the figure. The transfer characteristics of the rectifiers are also shown within the block.



It is desired to make full wave rectifier using above two half-wave rectifiers. The resultants circuit will be

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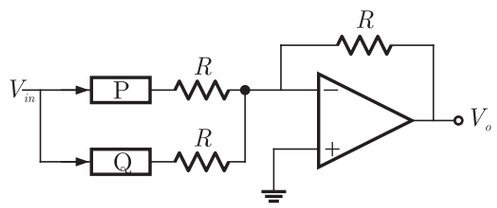
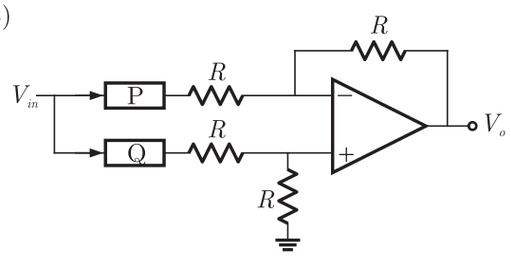
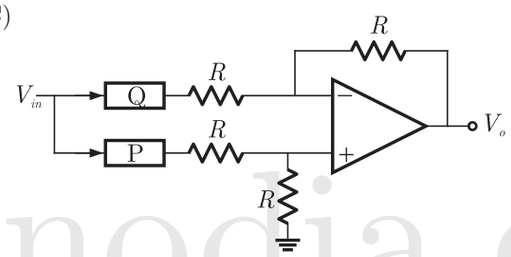
(A)



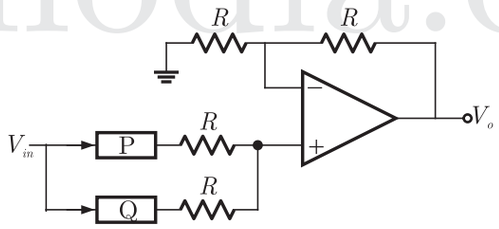
(B)



(C)



(D)



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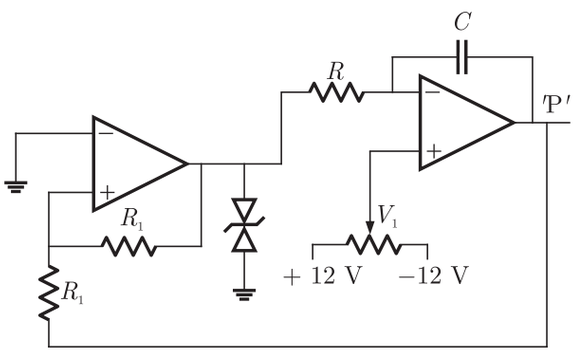
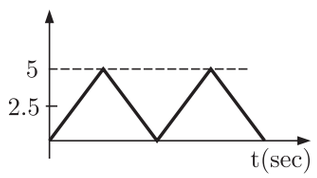
MCQ 1.8.42 A waveform generator circuit using OPAMPs is shown in the figure. It produces a triangular wave at point 'P' with a peak to peak voltage of 5 V for $V_i = 0$ V.

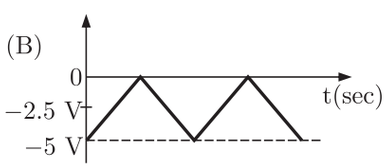


If the voltage V_i is made +2.5 V, the voltage waveform at point 'P' will become

(A)



(B)



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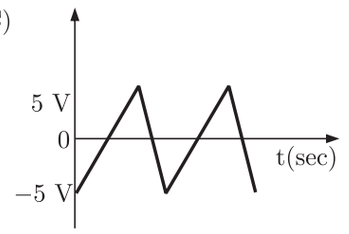
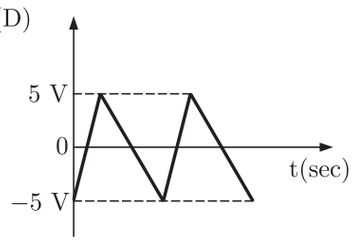
(C)

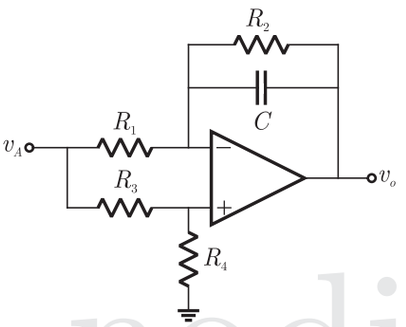


(D)



Statement for Linked Answer Questions 21 and 22.

A general filter circuit is shown in the figure :



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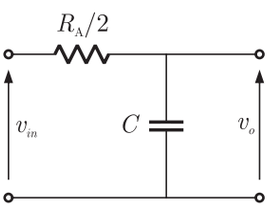
MCQ 1.8.43 If $R_1 = R_2 = R_A$ and $R_3 = R_4 = R_B$, the circuit acts as a

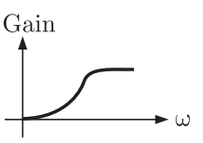
(A) all pass filter (B) band pass filter

(C) high pass filter (D) low pass filter

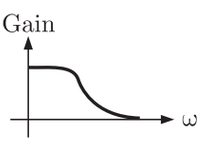
MCQ 1.8.44 The output of the filter in Q.21 is given to the circuit in figure :
The gain v/s frequency characteristic of the output (v_o) will be



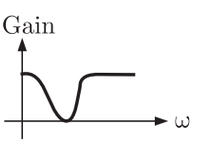
(A)



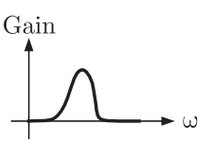
(B)



(C)



(D)



MCQ 1.8.45 A 3-line to 8-line decoder, with active low outputs, is used to implement a 3-variable Boolean function as shown in the figure

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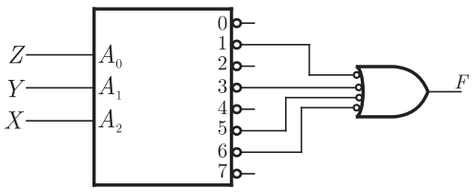

The simplified form of Boolean function $F(A,B,C)$ implemented in 'Product of Sum' form will be

(A) $(X+Z)(\overline{X}+\overline{Y}+\overline{Z})(Y+Z)$

(B) $(\overline{X}+\overline{Z})(X+Y+Z)(\overline{Y}+\overline{Z})$

(C) $(\overline{X}+\overline{Y}+Z)(\overline{X}+Y+Z)(X+\overline{Y}+Z)(X+Y+\overline{Z})$

(D) $(\overline{X}+\overline{Y}+Z)(\overline{X}+Y+\overline{Z})(X+\overline{Y}+Z)(X+\overline{Y}+\overline{Z})$

MCQ 1.8.46 The content of some of the memory location in an 8085 accumulator based system are given below

Address	Content
...	...
26FE	00
26FF	01
2700	02
2701	03
2702	04
...	...

The content of stack (SP), program counter (PC) and (H,L) are 2700 H, 2100 H and 0000 H respectively. When the following sequence of instruction are executed.

2100 H: DAD SP

2101 H: PCHL

the content of (SP) and (PC) at the end of execution will be

(A) PC = 2102 H, SP = 2700 H

(B) PC = 2700 H, SP = 2700 H

(C) PC = 2800 H, SP = 26FE H

(D) PC = 2A02 H, SP = 2702 H

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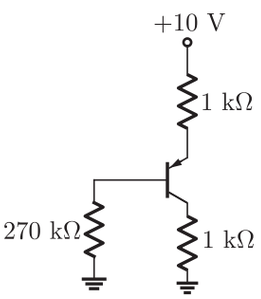
MCQ 1.8.47 The common emitter forward current gain of the transistor shown is $\beta_F = 100$



The transistor is operating in

(A) Saturation region

(B) Cutoff region

(C) Reverse active region

(D) Forward active region

MCQ 1.8.48 The three-terminal linear voltage regulator is connected to a 10 Ω load resistor as

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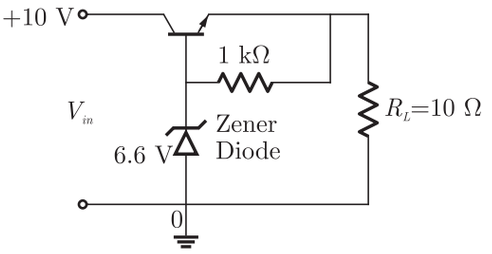
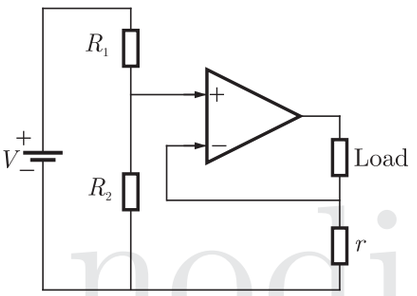
shown in the figure. If V_{in} is 10 V, what is the power dissipated in the transistor ?



(A) 0.6 W (B) 2.4 W

(C) 4.2 W (D) 5.4 W

MCQ 1.8.49 The circuit shown in the figure is



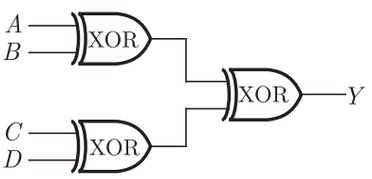
(A) a voltage source with voltage $\frac{rV}{R_1 < R_2}$

(B) a voltage source with voltage $\frac{r < R_2}{R_1} V$

(C) a current source with current $\left(\frac{r < R_2}{R_1 + R_2}\right)\frac{V}{r}$

(D) a current source with current $\left(\frac{R_2}{R_1 + R_2}\right)\frac{V}{r}$

MCQ 1.8.50 A, B, C and D are input, and Y is the output bit in the XOR gate circuit of the figure below. Which of the following statements about the sum S of A, B, C, D and Y is correct ?



(A) S is always with zero or odd

(B) S is always either zero or even

(C) $S = 1$ only if the sum of A, B, C and D is even

(D) $S = 1$ only if the sum of A, B, C and D is odd

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MCQ 1.8.51 The input signal V_{in} shown in the figure is a 1 kHz square wave voltage that alternates between $+7$ V and -7 V with a 50% duty cycle. Both transistor have the same current gain which is large. The circuit delivers power to the load resistor R_L. What is the efficiency of this circuit for the given input ? choose the

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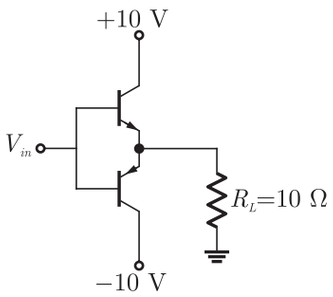
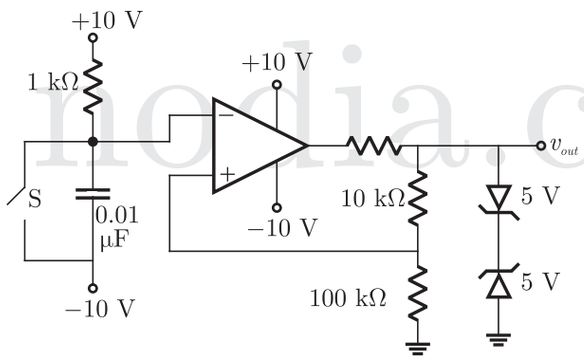
closest answer.



(A) 46%
(B) 55%
(C) 63%
(D) 92%

MCQ 1.8.52 The switch S in the circuit of the figure is initially closed, it is opened at time $t = 0$. You may neglect the zener diode forward voltage drops. What is the behavior of v_{out} for $t > 0$?



(A) It makes a transition from -5 V to $+5$ V at $t = 12.98\ \mu$s
(B) It makes a transition from -5 V to $+5$ V at $t = 2.57\ \mu$s
(C) It makes a transition from $+5$ V to -5 V at $t = 12.98\ \mu$s
(D) It makes a transition from $+5$ V to -5 V at $t = 2.57\ \mu$s

MCQ 1.8.53 The Octal equivalent of HEX and number AB.CD is
(A) 253.314
(B) 253.632
(C) 526.314
(D) 526.632

MCQ 1.8.54 IC 555 in the adjacent figure is configured as an astable multi-vibrator. It is enabled to to oscillate at $t = 0$ by applying a high input to pin 4. The pin description is : 1 and 8-supply; 2-trigger; 4-reset; 6-threshold 7-discharge. The waveform appearing across the capacitor starting from $t = 0$, as observed on a storage CRO is

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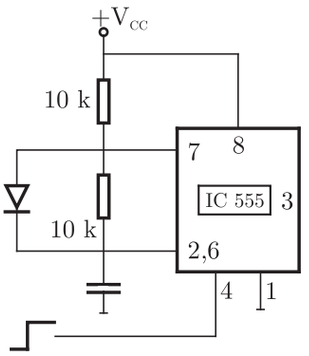
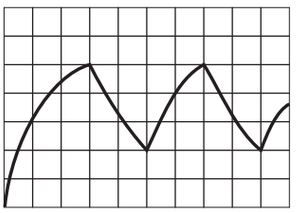
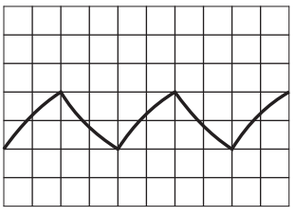


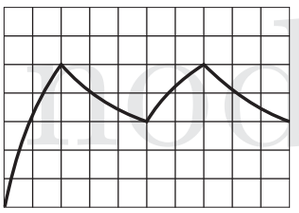
(A)



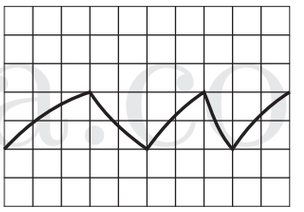
(B)



(C)



(D)



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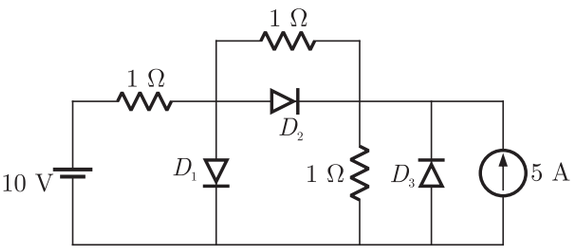
MCQ 1.8.55 What are the states of the three ideal diodes of the circuit shown in figure ?



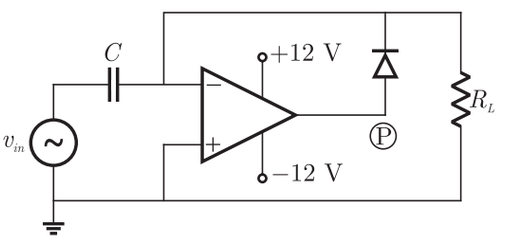
(A) D_1 ON, D_2 OFF, D_3 OFF

(B) D_1 OFF, D_2 ON, D_3 OFF

(C) D_1 ON, D_2 OFF, D_3 ON

(D) D_1 OFF, D_2 ON, D_3 ON

MCQ 1.8.56 For a given sinusoidal input voltage, the voltage waveform at point P of the clamper circuit shown in figure will be



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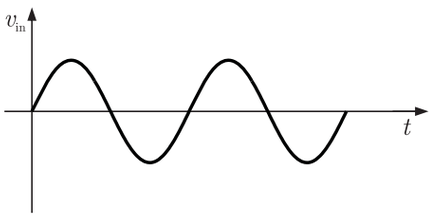
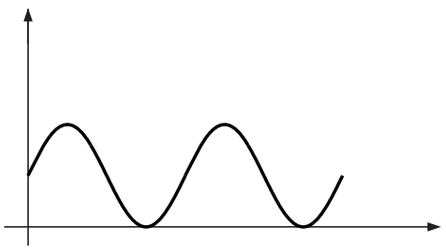
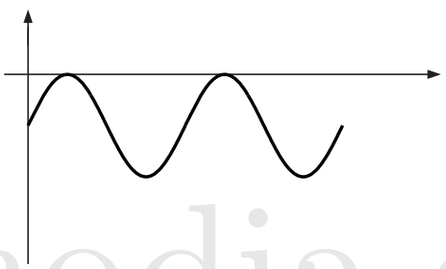


(A)



(B)



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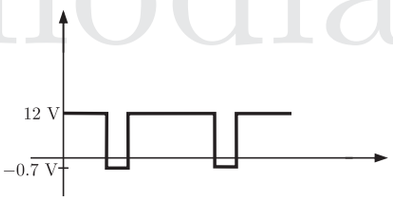
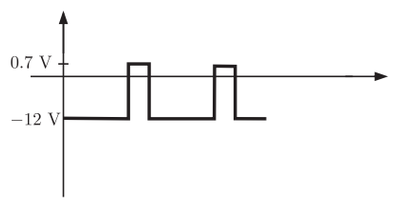
(C)



(D)



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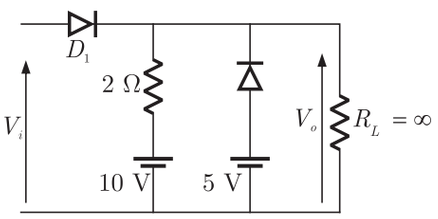
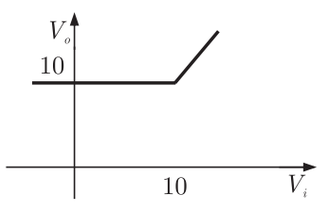
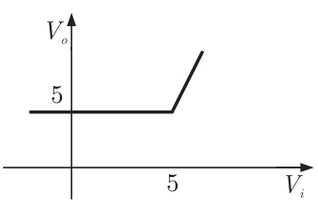
MCQ 1.8.57 Assuming the diodes D_1 and D_2 of the circuit shown in figure to be ideal ones, the transfer characteristics of the circuit will be



(A)



(B)



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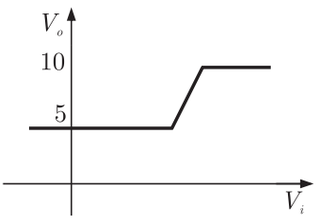
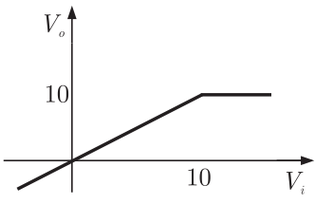
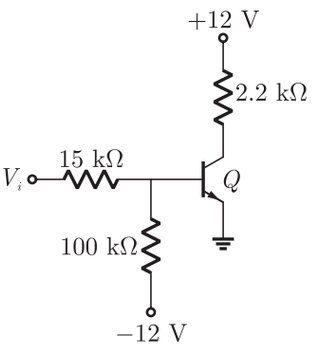
(C)



(D)

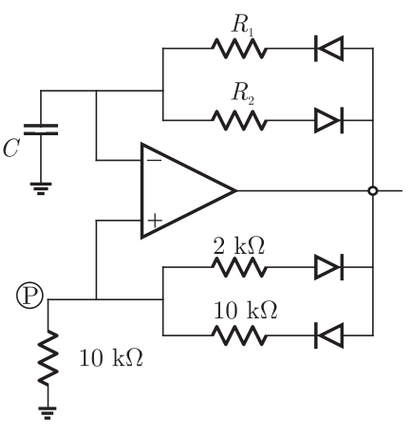


MCQ 1.8.58 Consider the circuit shown in figure. If the β of the transistor is 30 and I_{CBO} is 20 mA and the input voltage is $+5$ V, the transistor would be operating in

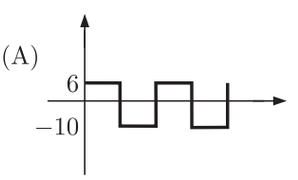


(A) saturation region
(B) active region
(C) breakdown region
(D) cut-off region

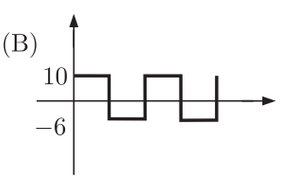
MCQ 1.8.59 A relaxation oscillator is made using OPAMP as shown in figure. The supply voltages of the OPAMP are ! 12 V. The voltage waveform at point P will be



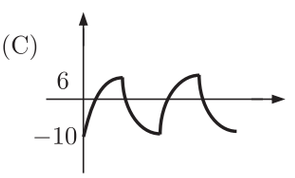
(A)



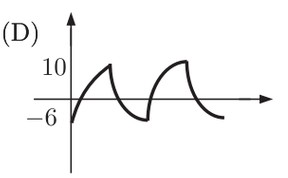
(B)



(C)



(D)



MCQ 1.8.60 A TTL NOT gate circuit is shown in figure. Assuming $V_{BE} = 0.7$ V of both the transistors, if $V_i = 3.0$ V, then the states of the two transistors will be

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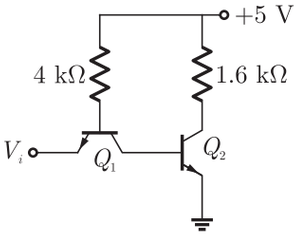
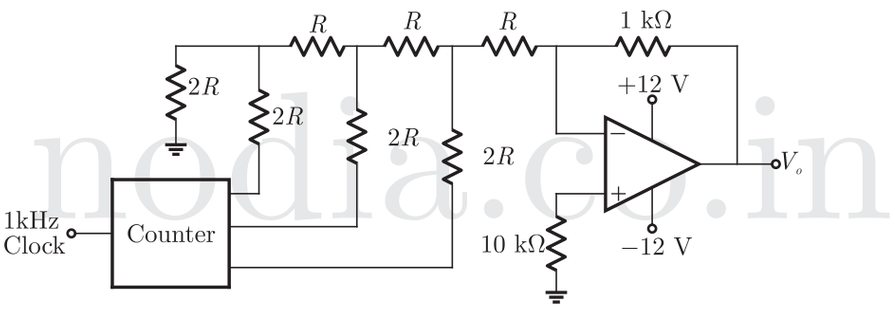
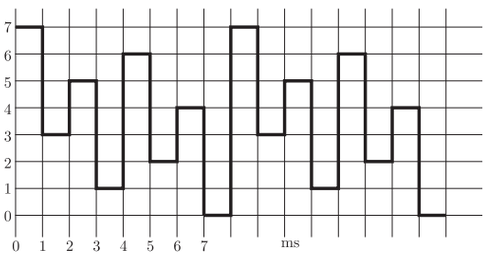


(A) Q_1 ON and Q_2 OFF
(B) Q_1 reverse ON and Q_2 OFF
(C) Q_1 reverse ON and Q_2 ON
(D) Q_1 OFF and Q_2 reverse ON

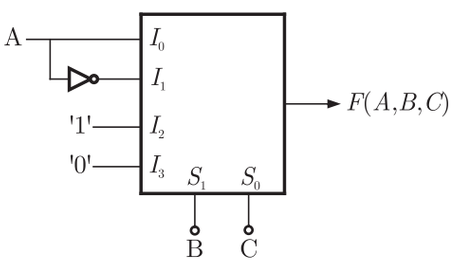
MCQ 1.8.61 A student has made a 3-bit binary down counter and connected to the R-$2R$ ladder type DAC, [Gain $= (-1\,\text{k}\Omega/2R)$] as shown in figure to generate a staircase waveform. The output achieved is different as shown in figure. What could be the possible cause of this error ?





(A) The resistance values are incorrect option.
(B) The counter is not working properly
(C) The connection from the counter of DAC is not proper
(D) The R and 2R resistance are interchanged

MCQ 1.8.62 A 4 # 1 MUX is used to implement a 3-input Boolean function as shown in figure. The Boolean function $F(A,B,C)$ implemented is



(A) $F(A,B,C) = \Sigma(1,2,4,6)$ (B) $F(A,B,C) = \Sigma(1,2,6)$
(C) $F(A,B,C) = \Sigma(2,4,5,6)$ (D) $F(A,B,C) = \Sigma(1,5,6)$

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MCQ 1.8.63 A software delay subroutine is written as given below :

```
DELAY :   MVI    H, 255D
          MVI    L, 255D
LOOP :    DCR    L
          JNZ    LOOP
          DCR    H
          JNZ    LOOP
```

How many times DCR L instruction will be executed ?

(A) 255 (B) 510

(C) 65025 (D) 65279

MCQ 1.8.64 In an 8085 A microprocessor based system, it is desired to increment the contents of memory location whose address is available in (D,E) register pair and store the result in same location. The sequence of instruction is

(A) XCHG
INR M

(B) XCHG
INX H

(C) INX D
XCHG

(D) INR M
XCHG

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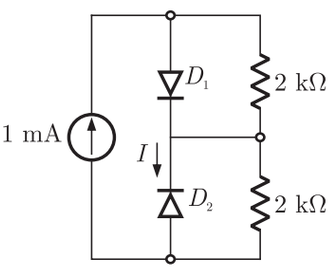
MCQ 1.8.65 Assume that D_1 and D_2 in figure are ideal diodes. The value of current is



(A) 0 mA (B) 0.5 mA

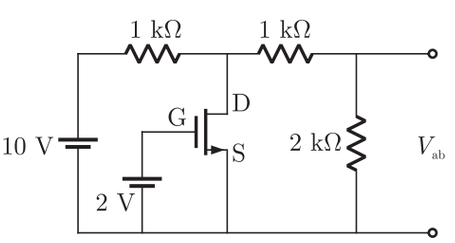
(C) 1 mA (D) 2 mA

MCQ 1.8.66 The 8085 assembly language instruction that stores the content of H and L register into the memory locations 2050_H and 2051_H, respectively is

(A) SPHL 2050_H (B) SPHL 2051_H

(C) SHLD 2050_H (D) STAX 2050_H

MCQ 1.8.67 Assume that the N-channel MOSFET shown in the figure is ideal, and that its threshold voltage is +1.0 V the voltage V_{ab} between nodes a and b is



(A) 5 V (B) 2 V

(C) 1 V (D) 0 V

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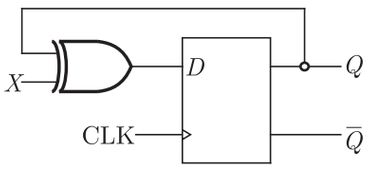
MCQ 1.8.68 The digital circuit shown in the figure works as



(A) JK flip-flop
(B) Clocked RS flip-flop
(C) T flip-flop
(D) Ring counter

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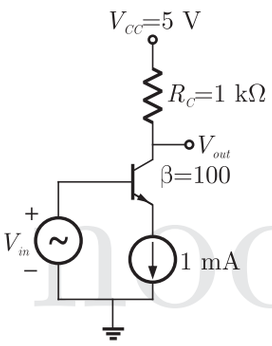
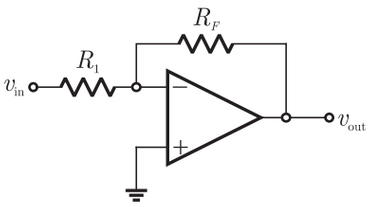
MCQ 1.8.69 The common emitter amplifier shown in the figure is biased using a 1 mA ideal current source. The approximate base current value is



(A) 0 μA
(B) 10 μA
(C) 100 μA
(D) 1000 μA

MCQ 1.8.70 Consider the inverting amplifier, using an ideal operational amplifier shown in the figure. The designer wishes to realize the input resistance seen by the small-signal source to be as large as possible, while keeping the voltage gain between -10 and -25. The upper limit on R_F is 1 MΩ. The value of R_1 should be



(A) Infinity
(B) 1 MΩ
(C) 100 kΩ
(D) 40 kΩ

MCQ 1.8.71 The typical frequency response of a two-stage direct coupled voltage amplifier is as shown in figure

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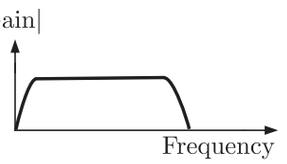
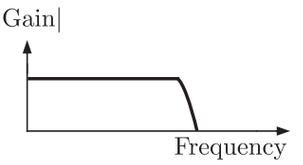
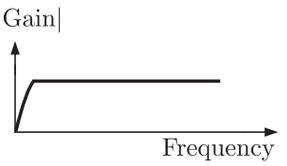
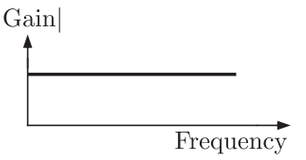
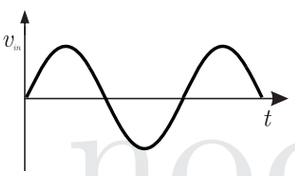
(A)


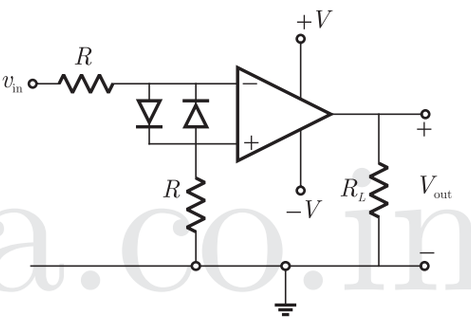
(B)


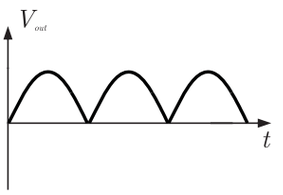
(C)


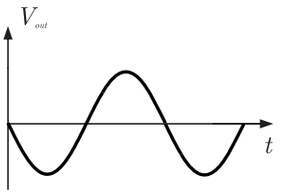
(D)


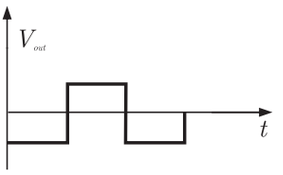
MCQ 1.8.72 In the given figure, if the input is a sinusoidal signal, the output will appear as shown

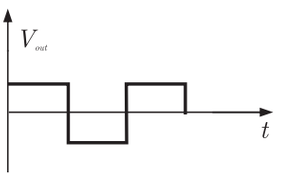




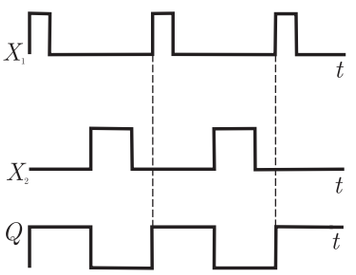
(A)


(B)


(C)


(D)


MCQ 1.8.73 Select the circuit which will produce the given output Q for the input signals X_1 and X_2 given in the figure



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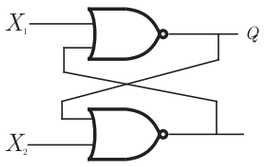
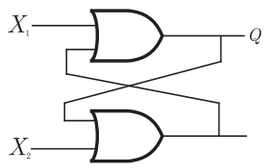
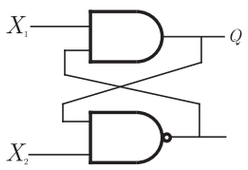
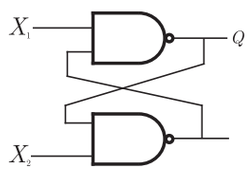
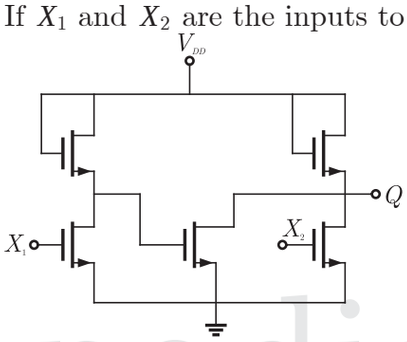
(A)


(B)


(C)


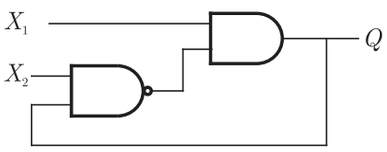
(D)


MCQ 1.8.74 If X_1 and X_2 are the inputs to the circuit shown in the figure, the output Q is



(A) $\overline{X_1 + X_2}$
(B) $\overline{X_1} : \overline{X_2}$
(C) $\overline{X_1} : X_2$
(D) $X_1 : \overline{X_2}$

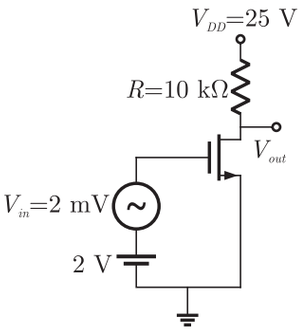
MCQ 1.8.75 In the figure, as long as $X_1 = 1$ and $X_2 = 1$, the output Q remains

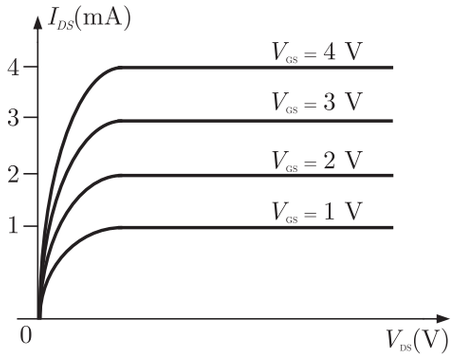


(A) at 1
(B) at 0
(C) at its initial value
(D) unstable

Data for Q. 76 and Q. 77 are given below. Solve the problems and choose the correct option.

Assume that the threshold voltage of the N-channel MOSFET shown in figure is + 0.75 V. The output characteristics of the MOSFET are also shown





MCQ 1.8.76 The transconductance of the MOSFET is
(A) 0.75 ms
(B) 1 ms

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(C) 2 ms (D) 10 ms

MCQ 1.8.77 The voltage gain of the amplifier is

(A) +5 (B) −7.5

(C) +10 (D) −10

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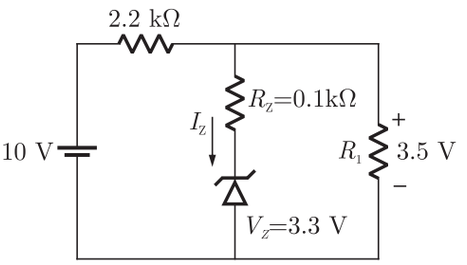
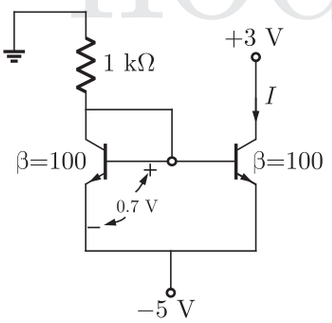
MCQ 1.8.78 The current through the Zener diode in figure is



(A) 33 mA (B) 3.3 mA

(C) 2 mA (D) 0 mA

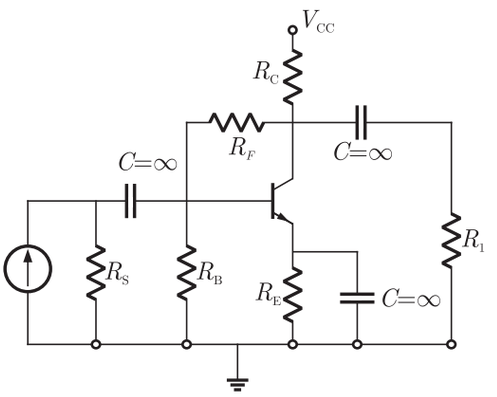
MCQ 1.8.79 Two perfectly matched silicon transistor are connected as shown in figure. The value of the current I is



(A) 0 mA (B) 2.3 mA

(C) 4.3 mA (D) 7.3 mA

MCQ 1.8.80 The feedback used in the circuit shown in figure can be classified as



(A) shunt-series feedback (B) shunt-shunt feedback

(C) series-shunt feedback (D) series-series feedback

MCQ 1.8.81 The digital circuit using two inverters shown in figure will act as

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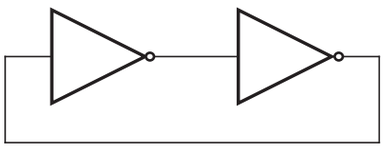
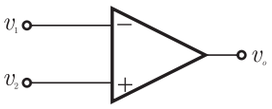


(A) a bistable multi-vibrator
(B) an astable multi-vibrator
(C) a monostable multi-vibrator
(D) an oscillator

MCQ 1.8.82 The voltage comparator shown in figure can be used in the analog-to-digital conversion as



(A) a 1-bit quantizer
(B) a 2-bit quantizer
(C) a 4-bit quantizer
(D) a 8-bit quantizer

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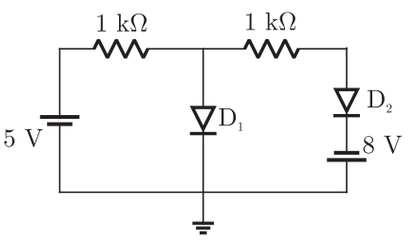
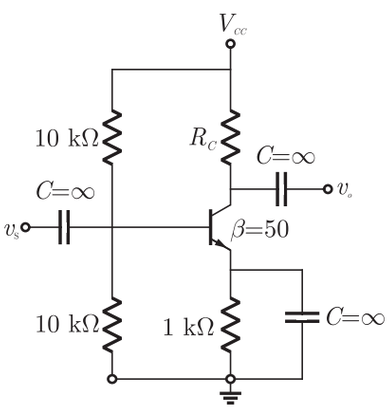
MCQ 1.8.83 Assuming that the diodes are ideal in figure, the current in diode D_1 is



(A) 9 mA (B) 5 mA
(C) 0 mA (D) −3 mA

MCQ 1.8.84 The trans-conductance g_m of the transistor shown in figure is 10 mS. The value of the input resistance R_{in} is



(A) 10.0 kΩ (B) 8.3 kΩ

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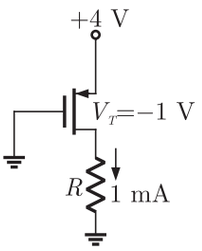
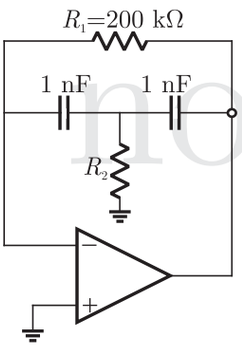
(C) 5.0 kΩ (D) 2.5 kΩ

MCQ 1.8.85 The value of R for which the PMOS transistor in figure will be biased in linear region is



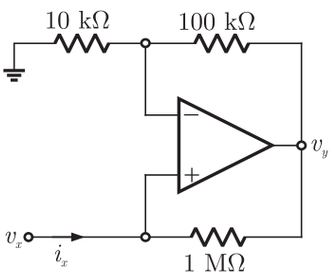
(A) 220 Ω (B) 470 Ω
(C) 680 Ω (D) 1200 Ω

MCQ 1.8.86 In the active filter circuit shown in figure, if Q = 1, a pair of poles will be realized with ω_0 equal to



(A) 1000 rad/s (B) 100 rad/s
(C) 10 rad/s (D) 1 rad/s

MCQ 1.8.87 The input resistance $R_{in} = v_x / i_x$ of the circuit in figure is



(A) +100 kΩ (B) −100 kΩ
(C) +1 MΩ (D) −1 MΩ

MCQ 1.8.88 The simplified form of the Boolean expression $Y = (\overline{A}\,\$\,BC + D)(\overline{A}\,\$\,D + \overline{B}\,\$\,\overline{C})$ can be written as

(A) $\overline{A}\,\$\,D + \overline{B}\,\$\,\overline{C}\,\$\,D$ (B) $AD + B\,\$\,\overline{C}\,\$\,D$
(C) $(\overline{A} + D)(\overline{B}\,\$\,C + \overline{D})$ (D) $A\,\$\,\overline{D} + BC\,\$\,\overline{D}$

MCQ 1.8.89 A digit circuit which compares two numbers $A_3A_2A_1A_0$ and $B_3B_2B_1B_0$ is shown in figure. To get output $Y = 0$, choose one pair of correct input numbers.

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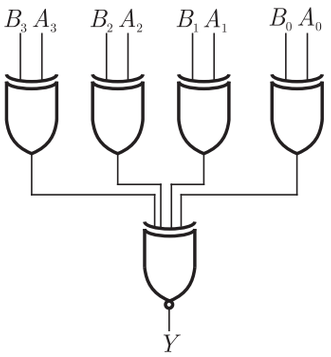
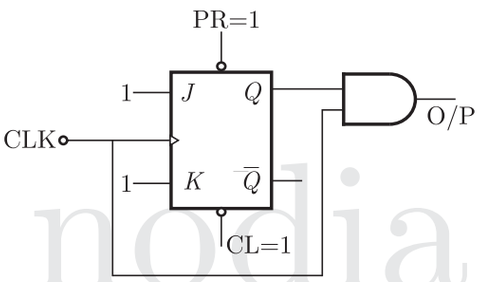


(A) 1010, 1010
(B) 0101, 0101
(C) 0010, 0010
(D) 1010, 1011

MCQ 1.8.90 The digital circuit shown in figure generates a modified clock pulse at the output. Choose the correct output waveform from the options given below.



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(A)

(B)

(C)

(D)

MCQ 1.8.91 If the following program is executed in a microprocessor, the number of instruction cycle it will take from START to HALT is

```
START   MVI A, 14H  ;   Move 14 H to register A
SHIFT   RLC         ;   Rotate left without carry
        JNZ SHIFT   ;   Jump on non-zero to SHIFT
        HALT
```

(A) 4
(B) 8
(C) 13
(D) 16

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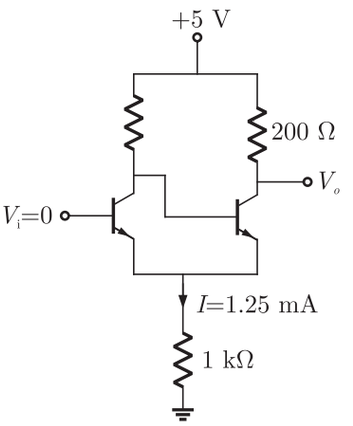
MCQ 1.8.92 In the Schmitt trigger circuit shown in figure, if $V_{CE(\text{sat})} = 0.1\,\text{V}$, the output logic low level (V_{OL}) is



(A) 1.25 V
(B) 1.35 V
(C) 2.50 V
(D) 5.00 V

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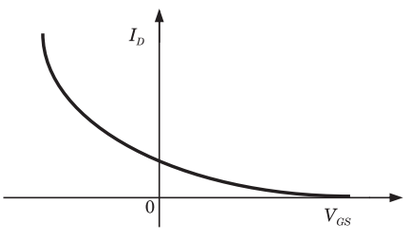
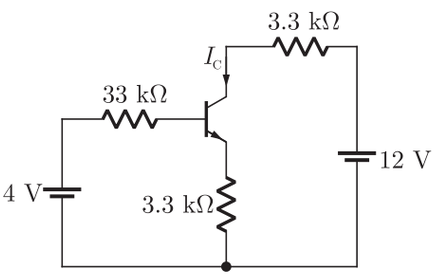
MCQ 1.8.93 The variation of drain current with gate-to-source voltage ($I_D - V_{GS}$ characteristic) of a MOSFET is shown in figure. The MOSFET is



(A) an n-channel depletion mode device
(B) an n-channel enhancement mode device
(C) an p-channel depletion mode device
(D) an p-channel enhancement mode device

MCQ 1.8.94 In the circuit of figure, assume that the transistor has $h_{fe} = 99$ and $V_{BE} = 0.7$ V. The value of collector current I_C of the transistor is approximately



(A) [3.3/3.3] mA
(B) [3.3/(3.3+3.3)] mA
(C) [3.3/.33] mA
(D) [3.3(33+3.3)] mA

MCQ 1.8.95 For the circuit of figure with an ideal operational amplifier, the maximum phase shift of the output v_{out} with reference to the input v_{in} is

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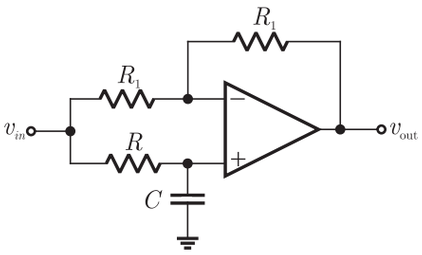
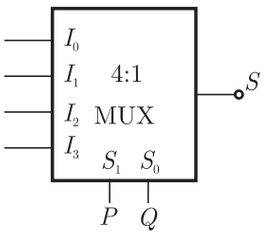


(A) 0c (B) -90c

(C) $+90$c (D) ! 180c

MCQ 1.8.96 Figure shows a 4 to 1 MUX to be used to implement the sum S of a 1-bit full adder with input bits P and Q and the carry input C_{in}. Which of the following combinations of inputs to I_0, I_1, I_2 and I_3 of the MUX will realize the sum S ?



(A) $I_0 = I_1 = C_{in}; I_2 = I_3 = \overline{C_{in}}$ (B) $I_0 = I_1 = \overline{C}_{in}; I_2 = I_3 = C_{in}$

(C) $I_0 = I_3 = C_{in}; I_1 = I_2 = \overline{C_{in}}$ (D) $I_0 = I_3 = \overline{C}_{in}; I_1 = I_2 = C_{in}$

MCQ 1.8.97 When a program is being executed in an 8085 microprocessor, its Program Counter contains

(A) the number of instructions in the current program that have already been executed

(B) the total number of instructions in the program being executed.

(C) the memory address of the instruction that is being currently executed

(D) the memory address of the instruction that is to be executed next

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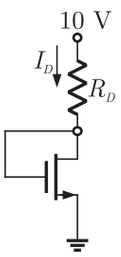
MCQ 1.8.98 For the n-channel enhancement MOSFET shown in figure, the threshold voltage $V_{th} = 2$ V. The drain current I_D of the MOSFET is 4 mA when the drain resistance R_D is 1 kΩ.If the value of R_D is increased to 4 kΩ, drain current I_D will become



(A) 2.8 mA (B) 2.0 mA

(C) 1.4 mA (D) 1.0 mA

MCQ 1.8.99 Assuming the operational amplifier to be ideal, the gain v_{out}/v_{in} for the circuit shown in figure is

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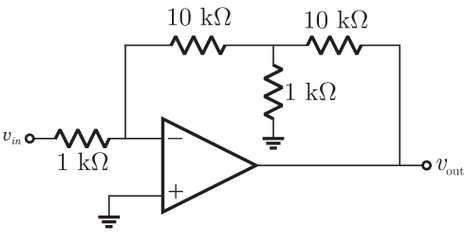
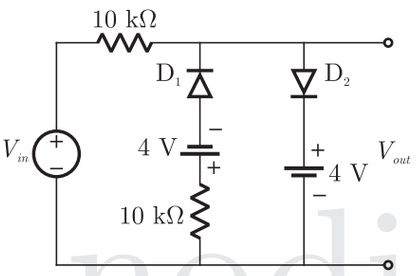


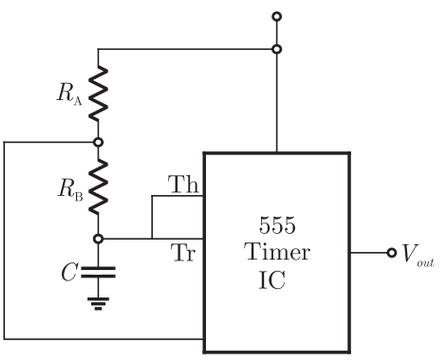
(A) -1 (B) -20
(C) -100 (D) -120

MCQ 1.8.100 A voltage signal $10\sin\omega t$ is applied to the circuit with ideal diodes, as shown in figure, The maximum, and minimum values of the output waveform V_{out} of the circuit are respectively



(A) $+10$ V and -10 V (B) $+4$ V and -4 V
(C) $+7$ V and -4 V (D) $+4$ V and -7 V

MCQ 1.8.101 The circuit of figure shows a 555 Timer IC connected as an astable multi-vibrator. The value of the capacitor C is 10 nF. The values of the resistors R_A and R_B for a frequency of 10 kHz and a duty cycle of 0.75 for the output voltage waveform are



(A) $R_A = 3.62\,\text{k}\Omega, R_B = 3.62\,\text{k}\Omega$
(B) $R_A = 3.62\,\text{k}\Omega, R_B = 7.25\,\text{k}\Omega$
(C) $R_A = 7.25\,\text{k}\Omega, R_B = 3.62\,\text{k}\Omega$
(D) $R_A = 7.25\,\text{k}\Omega, R_B = 7.25\,\text{k}\Omega$

MCQ 1.8.102 The boolean expression $\overline{X}\,Y\,\overline{Z} + \overline{XY}\,Z + XY\overline{Z} + X\overline{Y}Z + XYZ$ can be simplified to

(A) $X\overline{Z} + \overline{X}Z + YZ$ (B) $XY + \overline{Y}Z + Y\overline{Z}$
(C) $\overline{X}Y + YZ + XZ$ (D) $\overline{XY} + Y\overline{Z} + \overline{X}Z$

MCQ 1.8.103 The shift register shown in figure is initially loaded with the bit pattern 1010. Subsequently the shift register is clocked, and with each clock pulse the pattern gets shifted by one bit position to the right. With each shift, the bit at the serial

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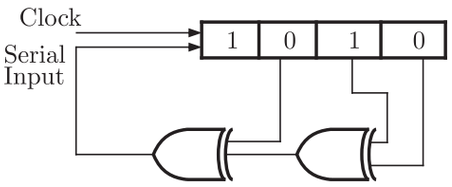
input is pushed to the left most position (msb). After how many clock pulses will the content of the shift register become 1010 again ?



(A) 3 (B) 7

(C) 11 (D) 15

MCQ 1.8.104 An X-Y flip-flop, whose Characteristic Table is given below is to be implemented using a J-K flip flop

X	Y	Q_{n+1}
0	0	1
0	1	Q_n
1	0	$\overline{Q}_n$
1	1	0

(A) $J = X, K = \overline{Y}$ (B) $J = \overline{X}, K = Y$

(C) $J = Y, K = \overline{X}$ (D) $J = \overline{Y}, K = X$

MCQ 1.8.105 A memory system has a total of 8 memory chips each with 12 address lines and 4 data lines, The total size of the memory system is

(A) 16 kbytes (B) 32 kbytes

(C) 48 kbytes (D) 64 kbytes

MCQ 1.8.106 The following program is written for an 8085 microprocessor to add two bytes located at memory addresses 1FFE and 1FFF

```
LXI  H, 1FFE
MOV  B, M
INR  L
MOV  A, M
ADD  B
INR  L
MOV  M, A
XOR  A
```

On completion of the execution of the program, the result of addition is found

(A) in the register A

(B) at the memory address 1000

(C) at the memory address 1F00

(D) at the memory address 2000

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MCQ 1.8.107 The frequency of the clock signal applied to the rising edge triggered D-flip-flop shown in Figure is 10 kHz. The frequency of the signal available at Q is.

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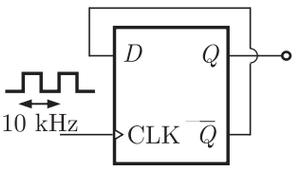
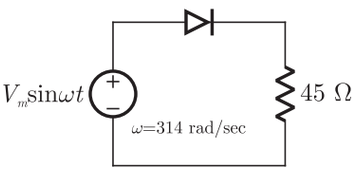


(A) 10 kHz (B) 2.5 kHz

(C) 20 kHz (D) 5 kHz

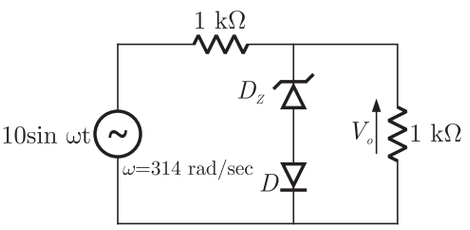
MCQ 1.8.108 The forward resistance of the diode shown in Figure is 5 Ω and the remaining parameters are same at those of an ideal diode. The dc component of the source current is



(A) $\frac{V_m}{50\pi}$ (B) $\frac{V_m}{50\pi\sqrt{2}}$

(C) $\frac{V_m}{100\pi\sqrt{2}}$ (D) $\frac{2V_m}{50\pi}$

MCQ 1.8.109 The cut-in voltage of both zener diode D_Z and diode D shown in Figure is 0.7 V, while break-down voltage of D_Z is 3.3 V and reverse break-down voltage of D is 50 V. The other parameters can be assumed to be the same as those of an ideal diode. The values of the peak output voltage (V_o) are



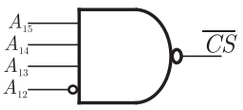
(A) 3.3 V in the positive half cycle and 1.4 V in the negative half cycle.

(B) 4 V in the positive half cycle and 5 V in the negative half cycle.

(C) 3.3 V in both positive and negative half cycles.

(D) 4 V in both positive and negative half cycle

MCQ 1.8.110 The logic circuit used to generate the active low chip select ($\overline{CS}$) by an 8085 microprocessor to address a peripheral is shown in Figure. The peripheral will respond to addresses in the range.



(A) E000-EFFF (B) 000E-FFFE

(C) 1000-FFFF (D) 0001-FFF1

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MCQ 1.8.111 A first order, low pass filter is given with $R = 50\,\Omega$ and $C = 5\,\mu$F. What is the frequency at which the gain of the voltage transfer function of the filter is 0.25 ?

(A) 4.92 kHz (B) 0.49 kHz

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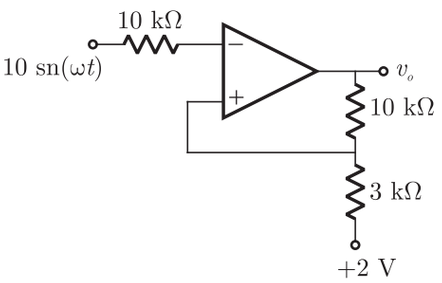
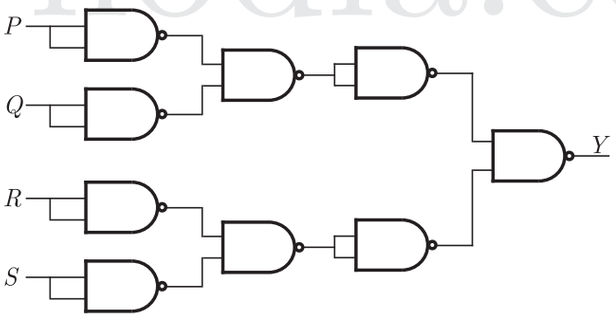
(C) 2.46 kHz (D) 24.6 kHz

MCQ 1.8.112 The output voltage (v_o) of the Schmitt trigger shown in Figure swings between $+15$ V and -15 V. Assume that the operational amplifier is ideal. The output will change from $+15$ V to -15 V when the instantaneous value of the input sine wave is



(A) 5 V in the positive slope only
(B) 5 V in the negative slope only
(C) 5 V in the positive and negative slopes
(D) 3 V in the positive and negative slopes.

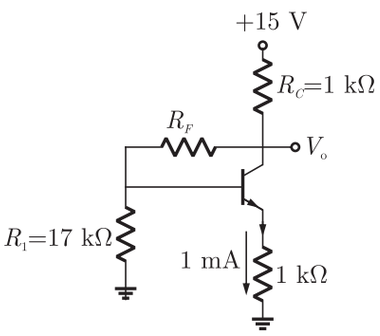
MCQ 1.8.113 For the circuit shown in Figure, the boolean expression for the output Y in terms of inputs P, Q, R and S is



(A) $\overline{P}+\overline{Q}+\overline{R}+\overline{S}$ (B) $P+Q+R+S$
(C) $(\overline{P}+\overline{Q})(\overline{R}+\overline{S})$ (D) $(P+Q)(R+S)$

Common Data Questions Q.114-116*

For the circuit shown in Figure, $I_E = 1$ mA, $\beta = 99$ and $V_{BE} = 0.7$ V



MCQ 1.8.114 The current through R_C is
(A) 0.99 mA (B) 1.1 mA

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(C) 1.20 mA (D) 1 mA

MCQ 1.8.115 Output voltage V_0 will be

(A) 16.1 Volt (B) 14 Volt

(C) 13.9 Volt (D) None of these

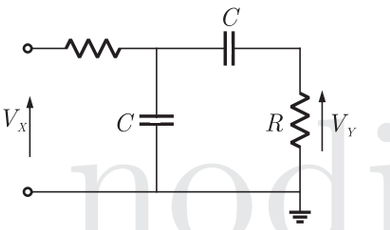
MCQ 1.8.116 Value of resistance R_F is

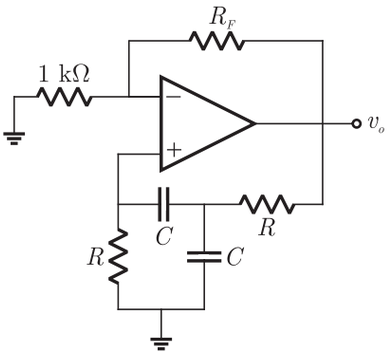
(A) 110.9 kΩ (B) 124.5 kΩ

(C) 130.90 kΩ (D) None of these

Common data question Q.117-119*.

The following network is used as a feedback circuit in an oscillator shown in figure to generate sinusoidal oscillations. Assuming that the operation amplifier is ideal. given that $R = 10\,\text{k}\Omega$ and $C = 100\,\text{pF}$





MCQ 1.8.117 The transfer function $\frac{V_y}{V_x}$ of the first network is

(A) $\frac{j\omega CR}{(1-\omega^2R^2C^2)+j3\omega CR}$ (B) $\frac{j\omega CR}{(1-\omega^2R^2C^2)+j2\omega CR}$

(C) $\frac{j\omega CR}{1+j3\omega CR}$ (D) $\frac{j\omega CR}{1+j2\omega CR}$

MCQ 1.8.118 The frequency of oscillation will be

(A) $\frac{1}{RC}$ (B) $\frac{1}{2RC}$

(C) $\frac{1}{4RC}$ (D) None of these

MCQ 1.8.119 Value of R_F is

(A) 1 kΩ (B) 4 kΩ

(C) 2 kΩ (D) 8 kΩ

MCQ 1.8.120 *The ripple counter shown in figure is made up of negative edge triggered J-K flip-flops. The signal levels at J and K inputs of all the flip flops are maintained at logic 1. Assume all the outputs are cleared just prior to applying the clock

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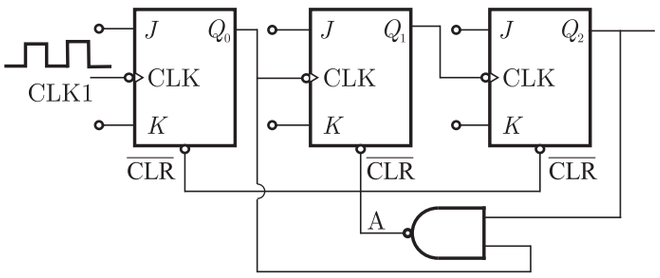
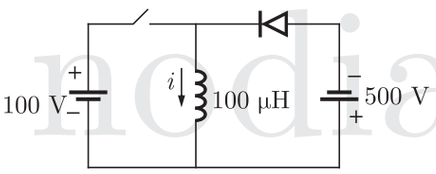
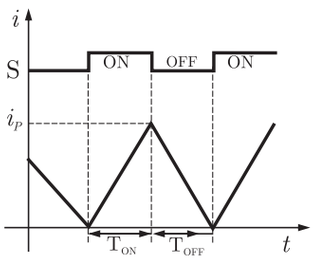
signal.
module no. of the counter is:



(A) 7
(B) 5
(C) 4
(D) 8

MCQ 1.8.121 *In Figure , the ideal switch S is switched on and off with a switching frequency $f = 10$ kHz. The switching time period is $T = t_{ON} + t_{OFF}$ μs. The circuit is operated in steady state at the boundary of continuous and discontinuous conduction, so that the inductor current i is as shown in Figure. Values of the on-time t_{ON} of the switch and peak current i_p. are

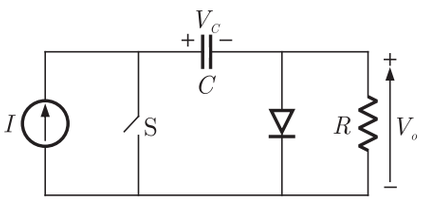




(A) 63.33 μsec, 63.33 A
(B) 63.33 μsec, 63.33 μA
(C) 66.66 μsec, 66.66 mA
(D) none of these

Common Data Questions Q.122-123*

In the circuit shown in Figure, the source I is a dc current source.The switch S is operated with a time period T and a duty ratio D. You may assume that the capacitance C has a finite value which is large enough so that the voltage. V_C has negligible ripple, calculate the following under steady state conditions, in terms of D, I and R



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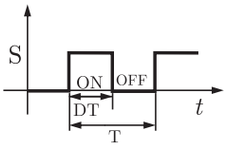

MCQ 1.8.122 The voltage V_c, with the polarity shown in Figure,

(A) $\frac{I}{C}$ (B) $\frac{I}{C}(1-DT)$

(C) $\frac{I}{C}(1-D)\,T$ (D) $-\frac{I}{C}T$

MCQ 1.8.123 The average output voltage V_0, with the polarity shown in figure

(A) $-\frac{I}{C}T$ (B) $-\frac{I}{2C}D^2T$

(C) $\frac{I}{2C}(1-DT)$ (D) $\frac{I}{2C}(1-D)\,T$

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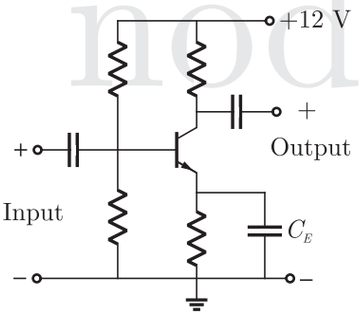
MCQ 1.8.124 In the single-stage transistor amplifier circuit shown in Figure, the capacitor C_E is removed. Then, the ac small-signal mid-band voltage gain of the amplifier



(A) increase (B) decreases

(C) is unaffected (D) drops to zero

MCQ 1.8.125 Among the following four, the slowest ADC (analog-to-digital converter) is

(A) parallel-comparator (i.e. flash) type

(B) successive approximation type

(C) integrating type

(D) counting type

MCQ 1.8.126 The output of a logic gate is "1" when all its inputs are at logic "0". The gate is either

(A) a NAND or an EX-OR gate

(B) a NOR or an EX-OR gate

(C) an AND or an EX-NOR gate

(D) a NOR or an EX-NOR gate

MCQ 1.8.127 The output f of the 4-to-1 MUX shown in Figure is

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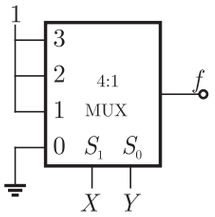

(A) $\overline{xy}+x$ (B) $x+y$

(C) $\overline{x}+\overline{y}$ (D) $xy+\overline{x}$

MCQ 1.8.128 An op-amp has an open-loop gain of 10^5 and an open-loop upper cut-off frequency of 10 Hz. If this op-amp is connected as an amplifier with a closed-loop gain of 100, then the new upper cut-off frequency is

(A) 10 Hz (B) 100 Hz

(C) 10 kHz (D) 100 kHz

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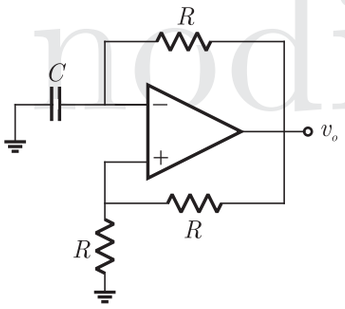
MCQ 1.8.129 For the oscillator circuit shown in Figure, the expression for the time period of oscillation can be given by (where $\tau = RC$)



(A) $\tau \ln 3$ (B) $2\tau \ln 3$

(C) $\tau \ln 2$ (D) $2\tau \ln 2$

MCQ 1.8.130 An Intel 8085 processor is executing the program given below.

```
        MVI A, 10 H
        MVI B, 10 H
BACK:   NOP
        ADD B
        RLC
        INC BACK
        HLT
```

The number of times that the operation NOP will be executed is equal to

(A) 1 (B) 2

(C) 3 (D) 4

MCQ 1.8.131 A sample-and-hold (S/H) circuit, having a holding capacitor of 0.1 nF, is used at the input of an ADC (analog-to-digital converter). The conversion time of the ADC is 1 μsec, and during this time, the capacitor should not loose more than 0.5% of the charge put across it during the sampling time. The maximum value of the input signal to the S/H circuit is 5 V. The leakage current of the S/H circuit should be less than

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(A) 2.5 mA (B) 0.25 mA

(C) 25.0 μA (D) 2.5 μA

MCQ 1.8.132 An op-amp, having a slew rate of 62.8 V/μsec, is connected in a voltage follower configuration. If the maximum amplitude of the input sinusoidal is 10 V, then the minimum frequency at which the slew rate limited distortion would set in at the output is

(A) 1.0 MHz (B) 6.28 MHz

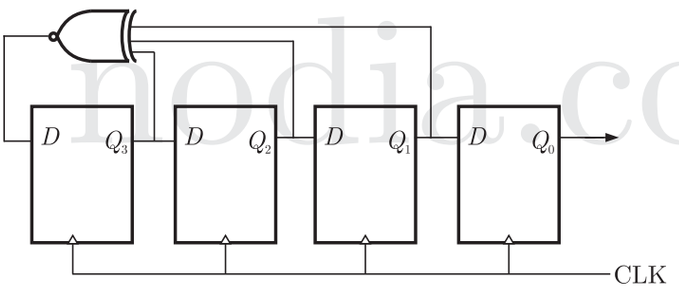
(C) 10.0 MHz (D) 62.8 MHz

MCQ 1.8.133 An n-channel JFET, having a pinch off voltage (V_p) of -5 V, shows a transconductance (g_m) of 1 mA/V when the applied gate -to-source voltage (V_{GS}) is -3 V. Its maximum transconductance (in mA/V) is

(A) 1.5 (B) 2.0

(C) 2.5 (D) 3.0

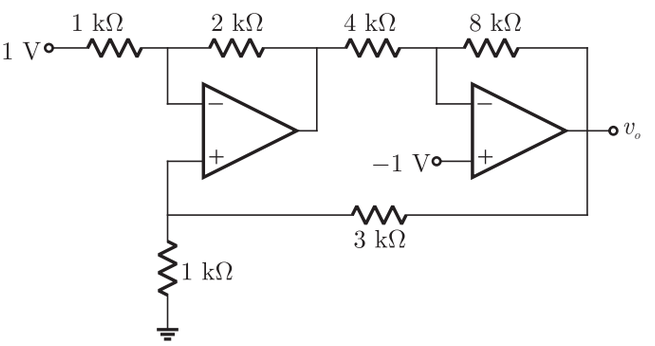
MCQ 1.8.134 *The circuit shown in the figure is a MOD-N ring counter. Value of N is (assume initial state of the counter is 1110 i.e. $Q_3Q_2Q_1Q_0$= 1110).



(A) 4 (B) 15

(C) 7 (D) 6

MCQ 1.8.135 *For the op-amp circuit shown in Figure, determine the output voltage v_o. Assume that the op-amps are ideal.



(A) $-\frac{8}{7}$ V (B) $-\frac{20}{7}$ V

(C) -10 V (D) None of these

Common Data Questions Q.136-137*.

The transistor in the amplifier circuit shown in Figure is biased at $I_C = 1$ mA Use $V_T = kT/q = 26$ mV, $\beta_0 = 200, r_b = 0$, and r_0 " 3

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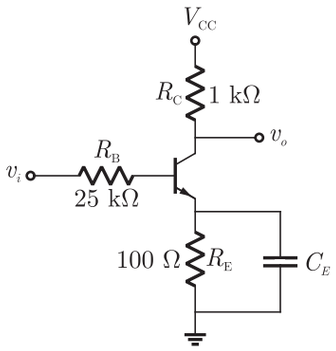

MCQ 1.8.136 Small-signal mid-band voltage gain v_o/v_i is

(A) -8 (B) 38.46

(C) -6.62 (D) -1

MCQ 1.8.137 What is the required value of C_E for the circuit to have a lower cut-off frequency of 10 Hz

(A) 0.15 mF (B) 1.59 mF

(C) 5 μF (D) 10 μF

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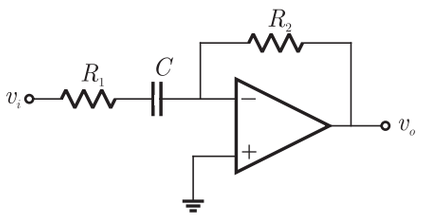
Common Data Questions Q.138-139*

For the circuit shown in figure



MCQ 1.8.138 The circuit shown is a

(A) Low pass filter (B) Band pass filter

(C) Band Reject filter (D) High pass filter

MCQ 1.8.139 If the above filter has a 3 dB frequency of 1 kHz, a high frequency input resistance of 100 kΩ and a high frequency gain of magnitude 10. Then values of R_1, R_2 and C respectively are :-

(A) 100 kΩ, 1000 kΩ, 15.9 nF

(B) 10 kΩ, 100 kΩ, 0.11 μF

(C) 100 kΩ, 1000 kΩ, 15.9 nF

(D) none of these

****

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SOLUTION

SOL 1.8.1 Option (C) is correct.

Let A denotes the position of switch at ground floor and B denotes the position of switch at upper floor. The switch can be either in up position or down position. Following are the truth table given for different combinations of A and B

A	B	Y(Bulb)
up(1)	up(1)	OFF(0)
Down(0)	Down(0)	OFF(0)
up(1)	Down(0)	ON(1)
Down(0)	up(1)	ON(1)

When the switches A and B are both up or both down, output will be zero (i.e. Bulb will be OFF). Any of the switch changes its position leads to the ON state of bulb. Hence, from the truth table, we get

$$Y = A \oplus B$$

i.e., the XOR gate

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SOL 1.8.2 Option (A) is correct.

The i/p voltage of the system is given as

$$\begin{aligned} V_{in} &= V_1 + V_f \\ &= V_1 + k\,V_{out} \\ &= V_1 + k\,A_0\,V_1 \qquad (V_{out} = A_0\,V_1) \\ &= V_1(1 + k\,A_0) \end{aligned}$$

Therefore, if k is increased then input voltage is also increased so, the input impedance increases. Now, we have

$$\begin{aligned} V_{out} &= A_0\,V_1 \\ &= A_0\,\frac{V_{in}}{(1 + k\,A_0)} \\ &= \frac{A_0\,V_{in}}{(1 + k\,A_0)} \end{aligned}$$

Since, V_{in} is independent of k when seen from output mode, the output voltage decreases with increase in k that leads to the decrease of output impedance. Thus, input impedance increases and output impedance decreases.

SOL 1.8.3 Option (B) is correct.

For the given ideal op-amp, negative terminal will be also ground (at zero voltage) and so, the collector terminal of the BJT will be at zero voltage.

i.e., $V_C = 0$ volt

The current in $1\,\text{k}\Omega$ resistor is given by

$$I = \frac{5 - 0}{1\,\text{k}\Omega} = 5\,\text{mA}$$

This current will flow completely through the BJT since, no current will flow into the ideal op-amp (I/P resistance of ideal op-amp is infinity). So, for BJT we have

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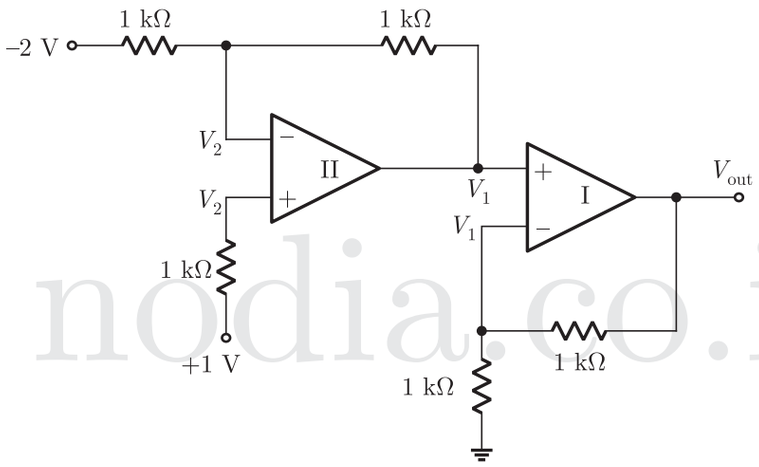
$$V_C = 0$$
$$V_B = 0$$
$$I_C = 5\,\text{mA}$$

i.e.,the base collector junction is reverse biased (zero voltage) therefore, the collector current (I_C) can have a value only if base-emitter is forward biased. Hence,

$$V_{BE} = 0.7 \text{ volts}$$
$$\Rightarrow \quad V_B - V_E = 0.7$$
$$\Rightarrow \quad 0 - V_{\text{out}} = 0.7$$
$$\text{or,} \quad V_{\text{out}} = -0.7 \text{ volt}$$

SOL 1.8.4 Option (C) is correct.



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For the given ideal op-Amps we can assume

$$V_2^- = V_2^+ = V_2 \text{ (ideal)}$$
$$V_1^+ = V_1^- = V_1 \text{ (ideal)}$$

So, by voltage division

$$V_1 = \frac{V_{\text{out}} \times 1}{2}$$
$$V_{\text{out}} = 2V_1$$

and, as the I/P current in Op-amp is always zero therefore, there will be no voltage drop across 1 KΩ in II op-amp

i.e., $V_2 = 1\,\text{V}$

Therefore,

$$\frac{V_1 - V_2}{1} = \frac{V_2 - (-2)}{1}$$
$$\text{or,} \quad V_1 - 1 = 1 + 2$$
$$\text{or,} \quad V_1 = 4$$

So,

$$V_{\text{out}} = 2V_1 = 8 \text{ volt}$$

SOL 1.8.5 Option (B) is correct.

For the given circuit, we can make the truth table as below

X	Y	Z
0	0	0
0	1	1
1	0	0
1	1	0

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Logic 0 means voltage is $v = 0$ volt and logic 1 means voltage is 5 volt

For $x = 0, y = 0$, Transistor is at cut off mode and diode is forward biased. Since, there is no drop across forward biased diode.

So, $Z = Y = 0$

For $x = 0, y = 1$, Again Transistor is in cutoff mode, and diode is forward biased. with no current flowing through resistor.

So, $Z = Y = 1$

For $x = 1, y = 0$, Transistor is in saturation mode and so, z directly connected to ground irrespective of any value of Y.

i.e., $Z = 0$ (ground)

Similarly for $X = Y = 1$

$Z = 0$ (ground)

Hence, from the obtained truth table, we get

$$Z = \overline{X}\,Y$$

SOL 1.8.6 Option (B) is correct.

From the given logic diagram, we obtain

$$X = (Q \oplus \overline{Q}) \cdot (\overline{Q} \oplus \overline{Q})$$
$$= \overline{0} = 1$$

So, the input is always '1' at T, since, clock is $-$ve edge trigged therefore, at the negative edge Q changes its state as shown in waveform below

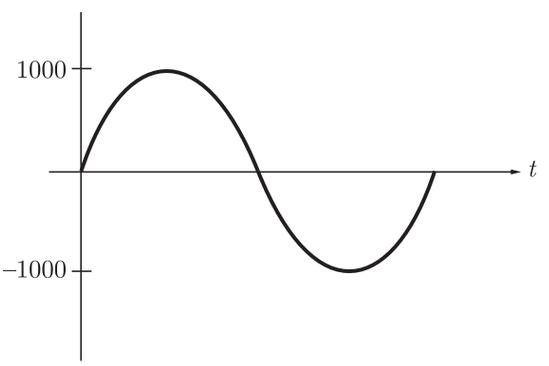
Hence, as obtained from the waveform, time period of Q is double to that of CLK I/p and so, frequency is $\frac{1}{2}$ of clock frequency

Thus, $f_Q = \frac{F_{CLK}}{2} = \frac{1}{2} = 0.5\,\text{kHz}$

SOL 1.8.7 Option (D) is correct.

Given, the input voltage

$$V_{YZ} = 100 \sin \omega t$$



For $+$ve half cycle

$$V_{YZ} > 0$$

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i.e., V_Y is a higher voltage than V_Z

So, the diode will be in cutoff region. Therefore, there will no voltage difference between X and W node.

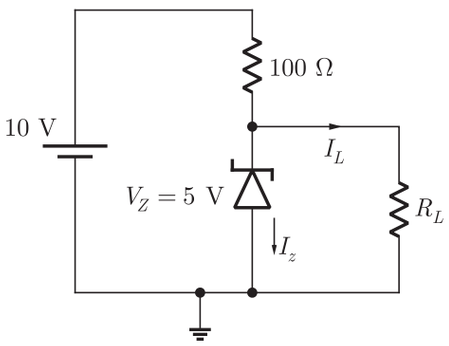
i.e., $V_{WX} = 0$

Now, for $-$ve half cycle all the four diodes will active and so, X and W terminal is short circuited

i.e., $V_{WX} = 0$

Hence, $V_{WX} = 0$ for all t

SOL 1.8.8 Option (B) is correct.



From the circuit, we have

$$I_s = I_Z + I_L$$

or, $$I_Z = I_s - I_L \quad (1)$$

Since, voltage across zener diode is 5 V so, current through 100 Ω resistor is obtained as

$$I_s = \frac{10-5}{100} = 0.05 \text{ A}$$

Therefore, the load current is given by

$$I_L = \frac{5}{R_L}$$

Since, for proper operation, we must have

$$I_Z \geq I_{knes}$$

So, from Eq. (1), we write

$$0.05 \text{ A} - \frac{5}{R_L} \geq 10 \text{ mA}$$

$$50 \text{ mA} - \frac{5}{R_L} \geq 10 \text{ mA}$$

$$40 \text{ mA} \geq \frac{5}{R_L}$$

$$40 \times 10^{-3} \geq \frac{5}{R_L}$$

$$\frac{1}{40 \times 10^{-3}} \leq \frac{R_L}{5}$$

$$\frac{5}{40 \times 10^{-3}} \leq R_L$$

or, $$125\,\Omega \leq R_L$$

Therefore, minimum value of $R_L = 125\,\Omega$

Now, we know that power rating of Zener diode is given by

$$P_R = V_Z I_{Z(\max)}$$

$I_{Z(\max)}$ is maximum current through zener diode in reverse bias. Maximum currrent through zener diode flows when load current is zero. i.e.,

$$I_{Z(\max)} = I_s = \frac{10-5}{100} = 0.05$$

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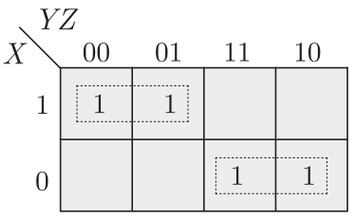
Therefore, $P_R = 5 \times 0.05\,\text{W}$
$= 250\,\text{mW}$

SOL 1.8.9 Option (A) is correct.

Prime implicants are the terms that we get by solving K-map



$$F = \underbrace{X\overline{Y} + \overline{X}Y}_{\text{prime implicants}}$$

SOL 1.8.10 Option (D) is correct.

Let $v > 0.7\,\text{V}$ and diode is forward biased. Applying Kirchoff's voltage law

$$10 - i \times 1\text{k} - v = 0$$

$$10 - \left[\frac{v - 0.7}{500}\right](1000) - v = 0$$

$$10 - (v - 0.7) \times 2 - v = 0$$

$$v = \frac{11.4}{3} = 3.8\,\text{V} > 0.7 \qquad \text{(Assumption is true)}$$

So, $i = \dfrac{v - 0.7}{500} = \dfrac{3.8 - 0.7}{500} = 6.2\,\text{mA}$

SOL 1.8.11 Option (B) is correct.

$Y = 1$, when $A > B$

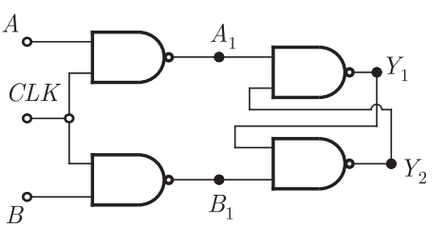
$$A = a_1a_0,\ B = b_1b_0$$

a_1	a_0	b_1	b_0	Y
0	1	0	0	1
1	0	0	0	1
1	0	0	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1

Total combination = 6

SOL 1.8.12 Option (A) is correct.

The given circuit is



Condition for the race-around

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It occurs when the output of the circuit (Y_1, Y_2) oscillates between '0' and '1' checking it from the options.

1. Option (A): When $CLK = 0$

Output of the NAND gate will be $A_1 = B_1 = \overline{0} = 1$. Due to these input to the next NAND gate, $Y_2 = \overline{Y_1 \cdot 1} = \overline{Y_1}$ and $Y_1 = \overline{Y_2 \cdot 1} = \overline{Y_2}$.

If $Y_1 = 0$, $Y_2 = \overline{Y_1} = 1$ and it will remain the same and doesn't oscillate.

If $Y_2 = 0$, $Y_1 = \overline{Y_2} = 1$ and it will also remain the same for the clock period. So, it won't oscillate for $CLK = 0$.

So, here race around doesn't occur for the condition $CLK = 0$.

2. Option (C): When $CLK = 1$, $A = B = 1$

$A_1 = B_1 = 0$ and so $Y_1 = Y_2 = 1$

And it will remain same for the clock period. So race around doesn't occur for the condition.

3. Option (D): When $CLK = 1$, $A = B = 0$

So, $A_1 = B_1 = 1$

And again as described for Option (B) race around doesn't occur for the condition.

So, Option (A) will be correct.

SOL 1.8.13 Option (D) is correct.

DC Analysis :

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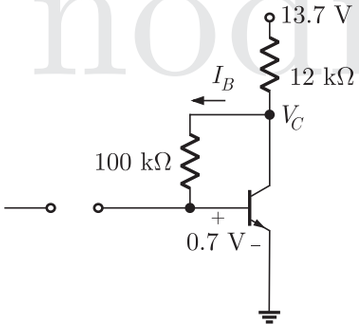


Using KVL in input loop,

$$V_C - 100I_B - 0.7 = 0$$

$$V_C = 100I_B + 0.7 \quad \text{...(i)}$$

$$I_C \simeq I_E = \frac{13.7 - V_C}{12k} = (\beta + 1)\, I_B$$

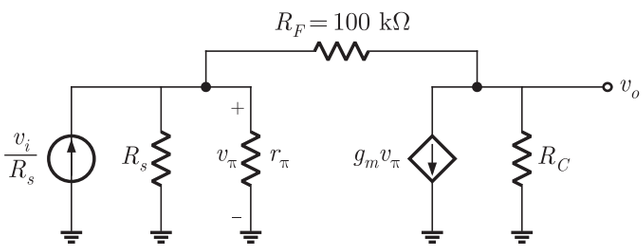
$$\frac{13.7 - V_C}{12 \times 10^3} = 100I_B \quad \text{...(ii)}$$

Solving equation (i) and (ii),

$$I_B = 0.01\,\text{mA}$$

Small Signal Analysis :

Transforming given input voltage source into equivalent current source.



This is a shunt-shunt feedback amplifier.

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Given parameters,

$$r_\pi = \frac{V_T}{I_B} = \frac{25\,\text{mV}}{0.01\,\text{mA}} = 2.5\,\text{k}\Omega$$

$$g_m = \frac{\beta}{r_\pi} = \frac{100}{2.5 \times 1000} = 0.04\,\text{s}$$

Writing KCL at output node

$$\frac{v_0}{R_C} + g_m v_\pi + \frac{v_0 - v_\pi}{R_F} = 0$$

$$v_0\left[\frac{1}{R_C} + \frac{1}{R_F}\right] + v_\pi\left[g_m - \frac{1}{R_F}\right] = 0$$

Substituting $R_C = 12\,\text{k}\Omega,\ R_F = 100\,\text{k}\Omega,\ g_m = 0.04\,\text{s}$

$$v_0(9.33 \times 10^{-5}) + v_\pi(0.04) = 0$$

$$v_0 = -428.72 V_\pi \qquad \text{...(i)}$$

Writing KCL at input node

$$\frac{v_i}{R_s} = \frac{v_\pi}{R_s} + \frac{v_\pi}{r_\pi} + \frac{v_\pi - v_o}{R_F} = v_\pi\left[\frac{1}{R_s} + \frac{1}{r_\pi} + \frac{1}{R_F}\right] - \frac{v_0}{R_F}$$

$$= v_\pi(5.1 \times 10^{-4}) - \frac{v_0}{R_F}$$

Substituting V_π from equation (i)

$$\frac{v_i}{R_s} = \frac{-5.1 \times 10^{-4}}{428.72} v_0 - \frac{v_0}{R_F}$$

$$\frac{v_i}{10 \times 10^3} = -1.16 \times 10^{-6} v_0 - 1 \times 10^{-5} v_0 \quad R_s = 10\,\text{k}\Omega \qquad \text{(source resistance)}$$

$$\frac{v_i}{10 \times 10^3} = -1.116 \times 10^{-5}$$

$$|A_v| = \left|\frac{v_0}{v_i}\right| = \frac{1}{10 \times 10^3 \times 1.116 \times 10^{-5}} \simeq 8.96$$

SOL 1.8.14 Option (D) is correct.

Let Q_{n+1} is next state and Q_n is the present state. From the given below figure.

$$D = Y = \overline{A} X_0 + A X_1$$

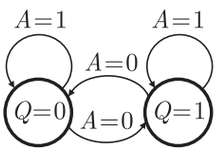
$$Q_{n+1} = D = \overline{A} X_0 + A X_1$$

$$Q_{n+1} = \overline{A}\,\overline{Q_n} + A Q_n \qquad X_0 = \overline{Q},\ X_1 = Q$$

If $A = 0$, $Q_{n+1} = \overline{Q_n}$ (toggle of previous state)

If $A = 1$, $Q_{n+1} = Q_n$

So state diagram is



SOL 1.8.15 Option (B) is correct.

First we obtain the transfer function.

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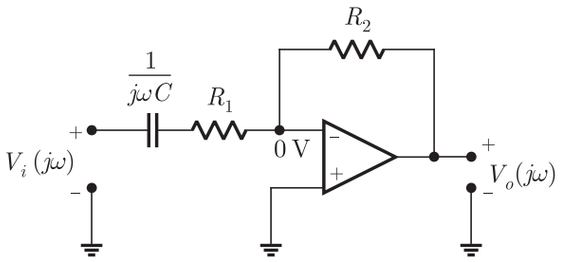

$$\frac{0-V_i(j\omega)}{\frac{1}{j\omega C}+R_1}+\frac{0-V_o(j\omega)}{R_2}=0$$

$$\frac{V_o(j\omega)}{R_2}=\frac{-V_i(j\omega)}{\frac{1}{j\omega C}+R_1}$$

$$V_o(j\omega)=-\frac{V_i(j\omega)\,R_2}{R_1-j\frac{1}{\omega C}}$$

At $\omega \to 0$ (Low frequencies), $\quad \frac{1}{\omega C} \to \infty$, so $V_o = 0$

At $\omega \to \infty$ (higher frequencies), $\quad \frac{1}{\omega C} \to 0$, so $V_o(j\omega) = -\frac{R_2}{R_1}V_i(j\omega)$

The filter passes high frequencies so it is a high pass filter.

$$H(j\omega)=\frac{V_o}{V_i}=\frac{-R_2}{R_1-j\frac{1}{\omega C}}$$

$$\left|H(\infty)\right|=\left|\frac{-R_2}{R_1}\right|=\frac{R_2}{R_1}$$

At 3 dB frequency, gain will be $\sqrt{2}$ times of maximum gain $[H(\infty)]$

$$\left|H(j\omega_0)\right|=\frac{1}{\sqrt{2}}\left|H(\infty)\right|$$

So, $$\frac{R_2}{\sqrt{R_1^2+\frac{1}{\omega_0^2C^2}}}=\frac{1}{\sqrt{2}}\left(\frac{R_2}{R_1}\right)$$

$$2R_1^2=R_1^2+\frac{1}{\omega_0^2C^2}\Rightarrow R_1^2=\frac{1}{\omega^2C^2}$$

$$\omega_0=\frac{1}{R_1C}$$

SOL 1.8.16 Option (D) is correct.

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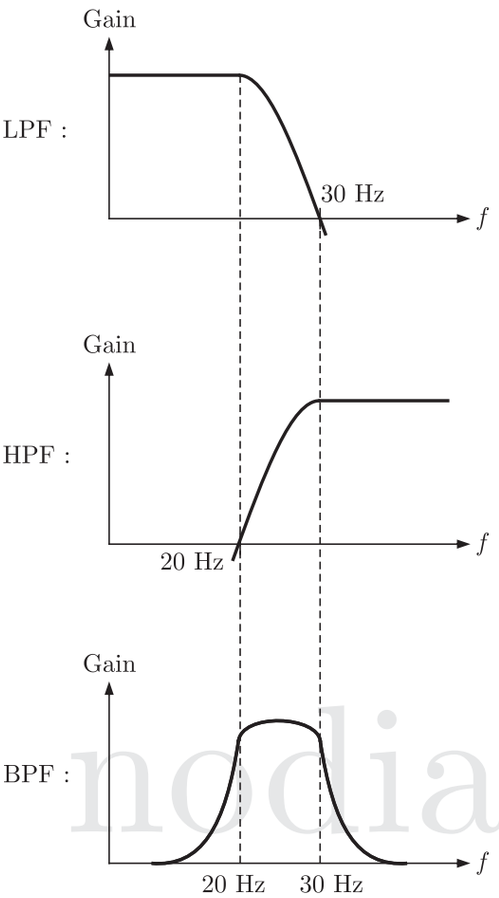

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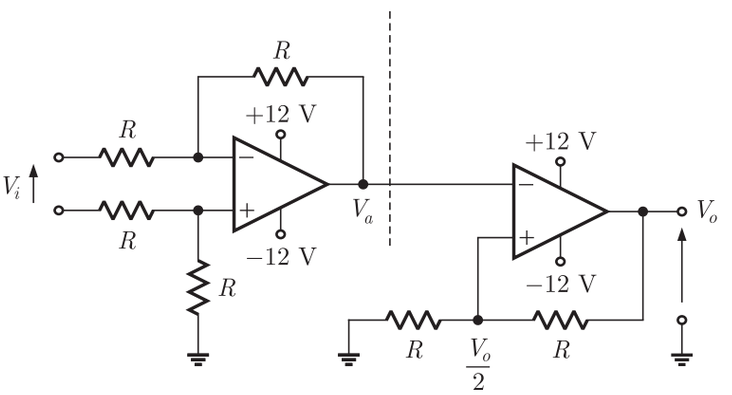
So, it will act as a Band pass filter.

SOL 1.8.17 Option (D) is correct.



The first half of the circuit is a differential amplifier (negative feedback)

$$V_a = -(V_i)$$

Second op-amp has a positive feedback, so it acts as an schmitt trigger.

Since

$V_a = -V_i$ this is a non-inverting schmitt trigger.

Threshold value

$$V_{TH} = \frac{12}{2} = 6\text{ V}$$

$$V_{TL} = -6\text{ V}$$

SOL 1.8.18 Option (A) is correct.

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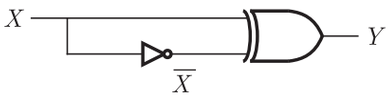


$$\begin{aligned} Y &= X \oplus \overline{X} \\ &= X\,\overline{\overline{X}} + \overline{X}X \\ &= XX + \overline{X}\,\overline{X} \\ &= X + \overline{X} = 1 \end{aligned}$$

SOL 1.8.19 Option (C) is correct.

LXI D, DISP
LP : CALL SUB
LP + 3

When CALL SUB is executed LP+3 value is pushed(inserted) in the stack.

POP H $\Rightarrow HL = LP + 3$

DAD D $\Rightarrow HL = HL + DE$

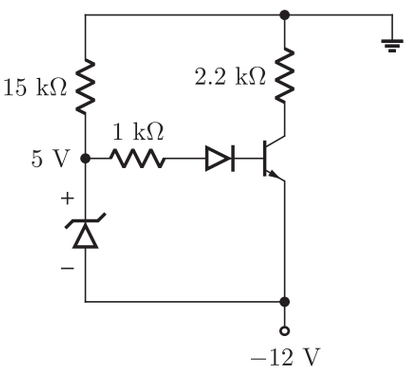
$= LP + 3 + DE$

PUSH H $\Rightarrow$ The last two value of the stack will be HL value i.e, $LP + DISP + 3$

SOL 1.8.20 Option (D) is correct.

Zener Diode is used as stabilizer.

The circuit is assumed to be as



We can see that both BE and BC Junction are forwarded biased. So the BJT is operating in saturation.

Collector current $I_C = \dfrac{12 - 0.2}{2.2k} = 5.36\,\text{mA}$

Note:- In saturation mode $I_C \neq \beta I_B$

SOL 1.8.21 Option (C) is correct.

The characteristics equation of the JK flip-flop is

$$Q_{n+1} = J\overline{Q}_n + \overline{K}Q_n$$ Q_{n+1} is the next state

From figure it is clear that

$$J = \overline{Q_B}\,; K = Q_B$$

The output of JK flip flop

$$Q_{A(n+1)} = \overline{Q_B}\,\overline{Q_A} + \overline{Q_B}\,Q_A = \overline{Q_B}(\overline{Q_A} + Q_A) = \overline{Q_B}$$

Output of T flip-flop

$$Q_{B(n+1)} = \overline{Q}_A$$

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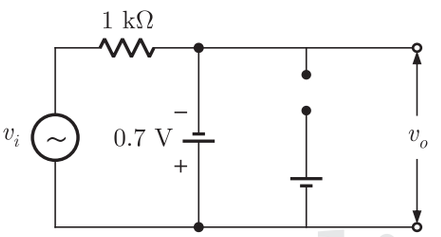
Clock pulse	Q_A	Q_B	$Q_{A(n+1)}$	$Q_{B(n+1)}$
Initially(t_n)	1	0	1	0
t_n+1	1	0	1	0
t_n+2	1	0	1	0
t_n+3	1	0	1	0

SOL 1.8.22 Option (C) is correct.

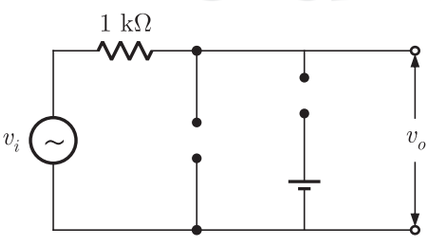
We can obtain three operating regions depending on whether the Zener and PN diodes are forward biased or reversed biased.

1. $v_i \le -0.7\,\text{V}$, zener diode becomes forward biased and diode D will be off so the equivalent circuit looks like



The output $v_o = -0.7\,\text{V}$

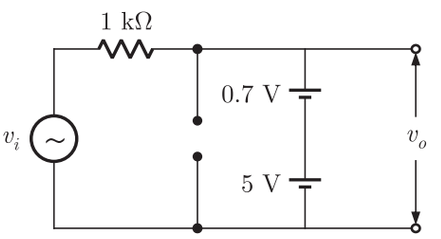
2. When $-0.7 < v_i \le 5.7$, both zener and diode D will be off. The circuit is



Output follows input i.e $v_o = v_i$

Note that zener goes in reverse breakdown(i.e acts as a constant battery) only when difference between its p-n junction voltages exceeds 10 V.

3. When $v_i > 5.7\,\text{V}$, the diode D will be forward biased and zener remains off, the equivalent circuit is



$$v_o = 5 + 0.7 = 5.7\,\text{V}$$

SOL 1.8.23 Option (B) is correct.

Since the op-amp is ideal

$$v_+ = v_- = +2 \text{ volt}$$

By writing node equation

$$\frac{v_- - 0}{R} + \frac{v_- - v_o}{2R} = 0$$

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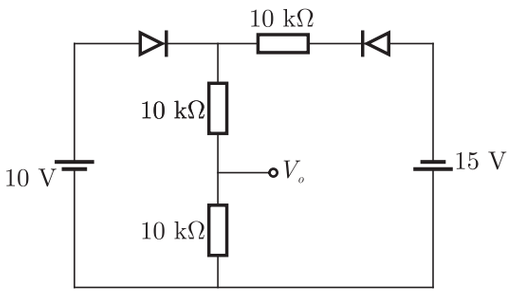
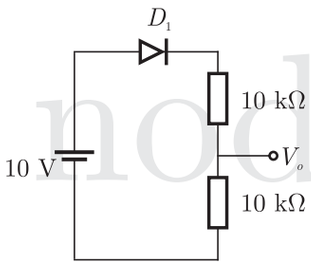
$$\frac{2}{R}+\frac{(2-v_o)}{2R}=0$$
$$4+2-v_o=0$$
$$v_o=6 \text{ volt}$$

SOL 1.8.24 Option (B) is correct.

Given circuit is,



We can observe that diode D_2 is always off, whether D_1,is on or off. So equivalent circuit is.



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D_1 is ON in this condition and

$$V_0=\frac{10}{10+10}\times 10$$
$$=5 \text{ volt}$$

SOL 1.8.25 Option (A) is correct.

By writing KVL equation for input loop (Base emitter loop)

$$10-(10\,\text{k}\Omega)I_B-V_{BE}-V_0=0 \qquad ...(1)$$

Emitter current $I_E=\frac{V_0}{100}$

$$I_C \simeq I_E=\beta I_B$$

So,
$$\frac{V_0}{100}=100I_B$$
$$I_B=\frac{V_0}{10\times 10^3}$$

Put I_B into equation (1)

$$10-(10\times 10^3)\frac{V_0}{10\times 10^3}-0.7-V_0=0$$
$$9.3-2V_0=0$$

$\Rightarrow$
$$V_0=\frac{9.3}{2}=4.65 \text{ A}$$

SOL 1.8.26 Option (A) is correct.

The circuit is

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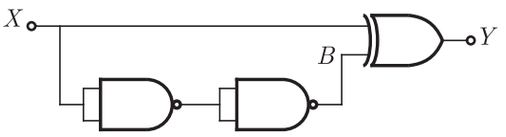
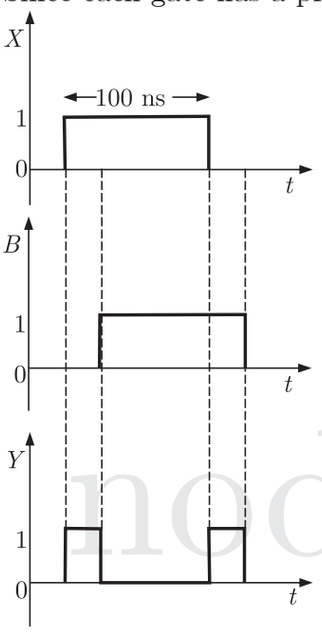


Output Y is written as

$$Y = X \oplus B$$

Since each gate has a propagation delay of 10 ns.



SOL 1.8.27 Option (D) is correct.

CALL, Address performs two operations

(1) PUSH PC $\Rightarrow$ Save the contents of PC (Program Counter) into stack.

$$\text{SP} = \text{SP} - 2 \text{ (decrement)}$$

$$((\text{SP})) \leftarrow (\text{PC})$$

(2) Addr stored in PC.

$$(\text{PC}) \leftarrow \text{Addr}$$

SOL 1.8.28 Option (B) is correct.

Function F can be minimized by grouping of all 1's in K-map as following.

X \ YZ	00	01	11	10
0	1	1	1	0
1	0	0	1	0

$$F = \overline{X}\,\overline{Y} + YZ$$

SOL 1.8.29 Option (D) is correct.

Since $F = \overline{X}\,\overline{Y} + YZ$

In option (D)

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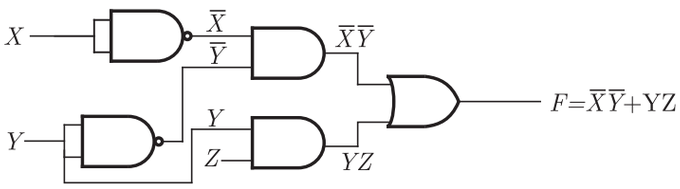
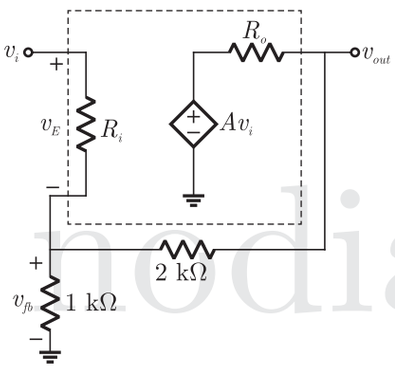


SOL 1.8.30 Option (A) is correct.
Figure shows current characteristic of diode during switching.

SOL 1.8.31 Option (B) is correct.
The increasing order of speed is as following
Magnetic tape> CD-ROM> Dynamic RAM>Cache Memory>Processor register

SOL 1.8.32 Option (B) is correct.
Equivalent circuit of given amplifier



Feedback samples output voltage and adds a negative feedback voltage (v_{fb}) to input.
So, it is a voltage-voltage feedback.

SOL 1.8.33 Option () is correct.
NOR and NAND gates considered as universal gates.

SOL 1.8.34 Option (A) is correct.
Let voltages at positive and negative terminals of op-amp are V_+ and V_- respectively, then

$$V_+ = V_- = V_s \text{ (ideal op-amp)}$$

In the circuit we have,

$$\frac{V_- - 0}{\frac{1}{Cs}} + \frac{V_- - V_0(s)}{R} = 0$$

$$(RCs)\,V_- + V_- - V_0(s) = 0$$

$$(1 + RCs)\,V_s = V_0(s)$$

Similarly current I_s is, $I_s = \dfrac{V_s - V_0}{R}$

$$I_s = \frac{RCs}{R} V_s$$

$$I_s = j\omega C V_s$$

$$I_s = |\omega C V_s| + +90^{\circ}$$

$$|I_s| = 2\pi f \# 10 \# 10^{-6} \# 10$$

$$|I_s| = 2 \# \pi \# 50 \# 10 \# 10^{-6} \# 10$$

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$$|I_s| = 10\pi \text{ mA, leading by } 90^\circ$$

SOL 1.8.35 Option (D) is correct.

Input and output power of a transformer is same

$$P_{in} = P_{out}$$

for emitter follower, $\text{voltage gain}\,(A_v) = 1$

$$\text{current gain}\,(A_i) > 1$$

$$\text{Power}\,(P_{out}) = A_v A_i P_{in}$$

Since emitter follower has a high current gain so $P_{out} > P_{in}$

SOL 1.8.36 Option (D) is correct.

For the given instruction set,

$$\text{XRA } A \,\&\, \text{XOR } A \text{ with } A \Rightarrow A = 0$$

$$\text{MVI } B, \text{F0 H} \,\&\, B = \text{F0 H}$$

$$\text{SUB } B \,\&\, A = A - B$$

$$A = 00000000$$

$$B = 11110000$$

$$\text{2's complement of } (-B) = \underline{00010000}$$

$$A + (-B) = A - B = 00010000$$

$$= 10\,\text{H}$$

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SOL 1.8.37 Option (D) is correct.

This is a schmitt trigger circuit, output can takes two states only.

$$V_{OH} = +6 \text{ volt}$$

$$V_{OL} = -3 \text{ volt}$$

Threshold voltages at non-inverting terminals of op-amp is given as

$$\frac{V_{TH} - 6}{2} + \frac{V_{TH} - 0}{1} = 0$$

$$3V_{TH} - 6 = 0$$

$$V_{TH} = 2 \text{ V} \quad \text{(Upper threshold)}$$

Similarly

$$\frac{V_{TL} - (-3)}{2} + \frac{V_{TL}}{1} = 0$$

$$3V_{TL} + 3 = 0$$

$$V_{TL} = -1 \text{ V} \quad \text{(Lower threshold)}$$

For $V_{in} < 2$ Volt, $V_0 = +6$ Volt

$V_{in} > 2$ Volt, $V_0 = -3$ Volt

$V_{in} < -1$ Volt $V_0 = +6$ Volt

$V_{in} > -1$ Volt $V_0 = -3$ Volt

Output waveform

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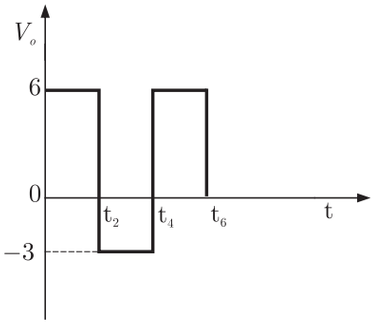
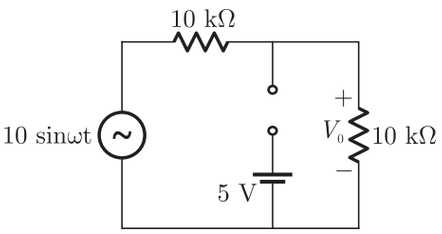


SOL 1.8.38 Option (A) is correct.

Assume the diode is in reverse bias so equivalent circuit is

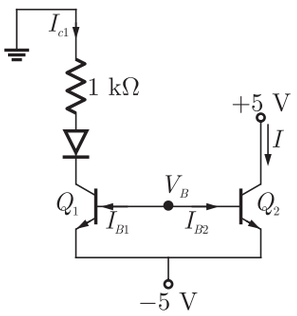


Output voltage $V_0 = \dfrac{10\sin\omega t}{10+10} \# 10 = 5\sin\omega t$

Due to resistor divider, voltage across diode $V_D < 0$ (always). So it in reverse bias for given input.

Output, $V_0 = 5\sin\omega t$

SOL 1.8.39 Option (C) is correct.



This is a current mirror circuit. Since β is high so $I_{C1} = I_{C2}, I_{B1} = I_{B2}$

$$V_B = (-5 + 0.7)$$
$$= -4.3 \text{ volt}$$

Diode D_1 is forward biased.

So, current I is, $I = I_{C2} = I_{C1}$

$$= \frac{0-(-4.3)}{1} = 4.3 \text{ mA}$$

SOL 1.8.40 Option (D) is correct.

In positive half cycle of input, diode D_1 is in forward bias and D_2 is off, the equivalent circuit is

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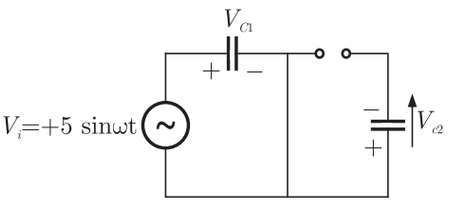
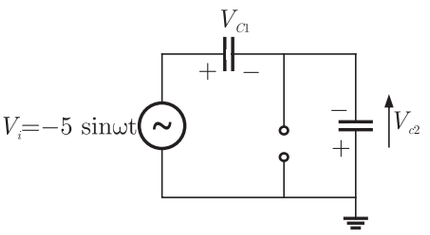


Capacitor C_1 will charge upto $+5$ volt. $V_{C1} = +5$ volt
In negative halt cycle diode D_1 is off and D_2 is on.



Now capacitor V_{C2} will charge upto -10 volt in opposite direction.

SOL 1.8.41 Option () is correct.
Let input V_{in} is a sine wave shown below

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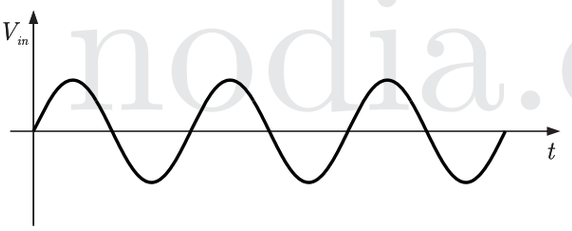
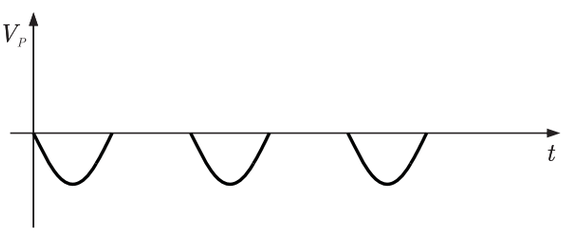
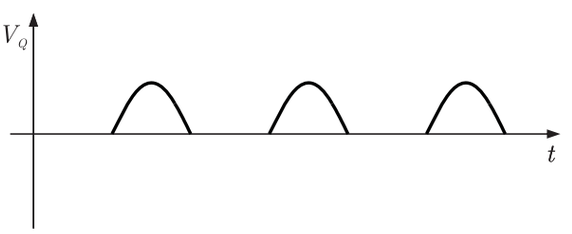


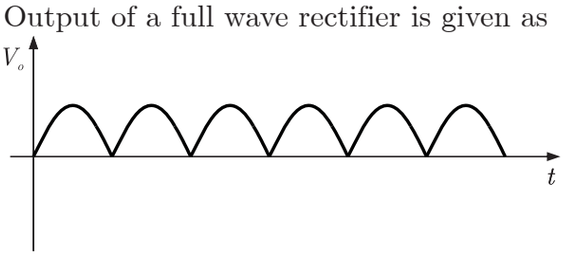
According to given transfer characteristics of rectifiers output of rectifier P is.



Similarly output of rectifier Q is



Output of a full wave rectifier is given as



To get output V_0

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$$V_0 = K(-V_P + V_Q) \qquad K - \text{gain of op-amp}$$

So, P should connected at inverting terminal of op-amp and Q with non-inverting terminal.

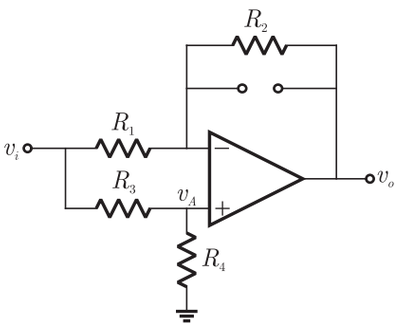
SOL 1.8.42 Option () is correct.

SOL 1.8.43 Option (C) is correct.

For low frequencies,

ω " 0, so $\frac{1}{\omega C}$ " 3

Equivalent circuit is,



Applying node equation at positive and negative input terminals of op-amp.

$$\frac{v_A - v_i}{R_1} + \frac{v_A - v_o}{R_2} = 0$$

$$2v_A = v_i + v_o, \qquad \because R_1 = R_2 = R_A$$

Similarly,

$$\frac{v_A - v_i}{R_3} + \frac{v_A - 0}{R_4} = 0$$

$$2v_A = v_{in}, \qquad \because R_3 = R_4 = R_B$$

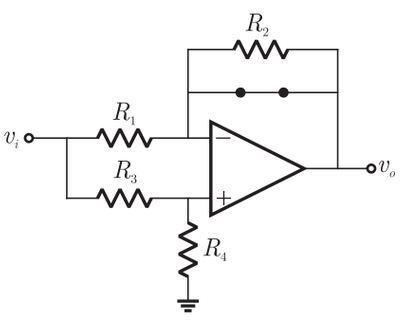
So, $v_o = 0$

It will stop low frequency signals.

For high frequencies,

ω " 3, then $\frac{1}{\omega C} \to 0$

Equivalent circuit is,



Output, $v_o = v_i$

So it will pass high frequency signal.

This is a high pass filter.

SOL 1.8.44 Option (D) is correct.

In Q.7.21 cutoff frequency of high pass filter is given by,

$$\omega_h = \frac{1}{2\pi R_A C}$$

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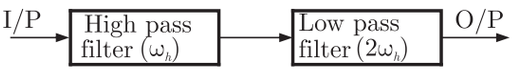
Here given circuit is a low pass filter with cutoff frequency,

$$\omega_L = \frac{1}{2\pi \frac{R_A}{2} C} = \frac{2}{2\pi R_A C}$$

$$\omega_L = 2\omega_h$$

When both the circuits are connected together, equivalent circuit is,



So this is is Band pass filter, amplitude response is given by.

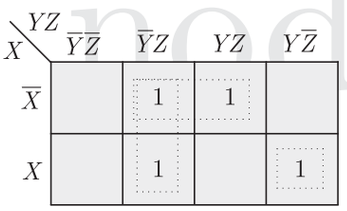
SOL 1.8.45 Option (B) is correct.

In SOP form, F is written as

$$F = \Sigma m(1,3,5,6)$$

$$= \overline{X}\,\overline{Y}Z + \overline{X}\,Y\overline{Z} + X\overline{Y}Z + XY\overline{Z}$$

Solving from K- map



$$F = \overline{X}Z + \overline{Y}Z + XY\overline{Z}$$

In POS form $F = (Y+Z)(X+Z)(\overline{X}+\overline{Y}+\overline{Z})$

Since all outputs are active low so each input in above expression is complemented

$$F = (\overline{Y}+\overline{Z})(\overline{X}+\overline{Z})(X+Y+Z)$$

SOL 1.8.46 Option (B) is correct.

Given that SP = 2700 H

PC = 2100 H

HL = 0000 H

Executing given instruction set in following steps,

DAD SP & Add register pair (SP) to HL register

HL = HL + SP

HL = 0000 H + 2700 H

HL = 2700 H

PCHL & Load program counter with HL contents

PC = HL = 2700 H

So after execution contents are,

PC = 2700 H, HL = 2700 H

SOL 1.8.47 Option (D) is correct.

If transistor is in normal active region, base current can be calculated as following,

By applying KVL for input loop,

$$10 - I_C(1 \# 10^3) - 0.7 - 270 \# 10^3 I_B = 0$$

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$$\beta I_B + 270\, I_B = 9.3 \text{ mA}, \qquad \because I_C = \beta I_B$$
$$I_B(\beta + 270) = 9.3 \text{ mA}$$
$$I_B = \frac{9.3 \text{ mA}}{270 + 100} = 0.025 \text{ mA}$$

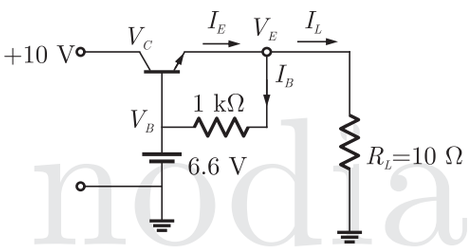
In saturation, base current is given by,

$$10 - I_C(1) - V_{CE} - I_E(1) = 0$$
$$\frac{10}{2} = I_{C\,(\text{sat})} \qquad I_C \approx I_E$$
$$V_{CE} \approx 0$$
$$I_{C\,(\text{sat})} = 5 \text{ mA}$$
$$I_{B(\text{sat})} = \frac{I_{C\,(\text{sat})}}{\beta} = \frac{5}{100} = .050 \text{ mA}$$

I_B 1 $I_{B(\text{sat})}$, so transistor is in forward active region.

SOL 1.8.48 Option (B) is correct.

In the circuit



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We can analyze that the transistor is operating in active region.

$$V_{BE(\text{ON})} = 0.6 \text{ volt}$$
$$V_B - V_E = 0.6$$
$$6.6 - V_E = 0.6$$
$$V_E = 6.6 - 0.6 = 6 \text{ volt}$$

At emitter (by applying KCL),

$$I_E = I_B + I_L$$
$$I_E = \frac{6 - 6.6}{1\,\text{k}\Omega} + \frac{6}{10\,\Omega} \approx 0.6 \text{ amp}$$

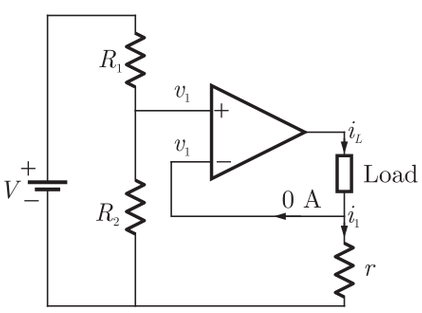
$V_{CE} = V_C - V_E = 10 - 6 = 4$ volt

Power dissipated in transistor is given by.

$$P_T = V_{CE} \# I_C = 4 \# 0.6 \qquad \because I_C \approx I_E = 0.6 \text{ amp}$$
$$= 2.4 \text{ W}$$

SOL 1.8.49 Option (D) is correct.

This is a voltage-to-current converter circuit. Output current depends on input voltage.



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Since op-amp is ideal $v_+ = v_- = v_1$

Writing node equation.

$$\frac{v_1 - v}{R_1} + \frac{v_1 - 0}{R_2} = 0$$

$$v_1\left(\frac{R_1 + R_2}{R_1 R_2}\right) = \frac{V}{R_1}$$

$$v_1 = V\left(\frac{R_2}{R_1 + R_2}\right)$$

Since the op-amp is ideal therefore

$$i_L = i_1 = \frac{v_1}{r} = \frac{V}{r}\left(\frac{R_2}{R_1 + R_2}\right)$$

SOL 1.8.50 Option (D) is correct.

In the circuit output Y is given as

$$Y = [A \ \mathbf{5} \ B] \ \mathbf{5} \ [C \ \mathbf{5} \ D]$$

Output Y will be 1 if no. of 1's in the input is odd.

SOL 1.8.51 Option () is correct.

This is a class-B amplifier whose efficiency is given as

$$\eta = \frac{\pi}{4}\frac{V_P}{V_{CC}}$$

where $V_P \rightarrow$ peak value of input signal

$V_{CC} \rightarrow$ supply voltage

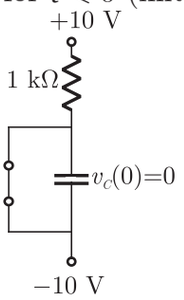
here $V_P = 7$ volt, $V_{CC} = 10$ volt

so, $$\eta = \frac{\pi}{4} \times \frac{7}{10} \times 100 = 54.95\% \simeq 55\%$$

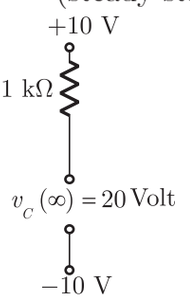
SOL 1.8.52 Option (B) is correct.

In the circuit the capacitor starts charging from 0 V (as switch was initially closed) towards a steady state value of 20 V.

for $t < 0$ (initial)



for $t \rightarrow \infty$ (steady state)



So at any time t, voltage across capacitor (i.e. at inverting terminal of op-amp) is given by

$$v_c(t) = v_c(\infty) + [v_c(0) - v_c(\infty)]e^{\frac{-t}{RC}}$$

$$v_c(t) = 20(1 - e^{\frac{-t}{RC}})$$

Voltage at positive terminal of op-amp

$$\frac{v_+ - v_{out}}{10} + \frac{v_+ - 0}{100} = 0$$

$$v_+ = \frac{10}{11}v_{out}$$

Due to zener diodes, $-5 \# v_{out} \# +5$

So, $$v_+ = \frac{10}{11}(5) \ \text{V}$$

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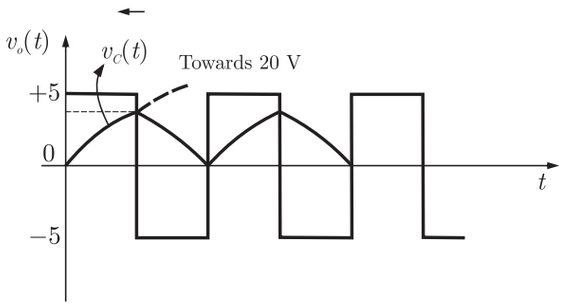
Transistor form -5 V to $+5$ V occurs when capacitor charges upto v_+.

So
$$20(1-e^{-t/RC}) = \frac{10 \# 5}{11}$$
$$1-e^{-t/RC} = \frac{5}{22}$$
$$\frac{17}{22} = e^{-t/RC}$$
$$t = RC \ln\left(\frac{22}{17}\right) = 1 \# 10^{3} \# .01 \# 10^{-6} \# 0.257 = 2.57\ \mu\text{sec}$$

Voltage waveforms in the circuit is shown below



SOL 1.8.53 Option (B) is correct.

First convert the given number from hexadecimal to its binary equivalent, then binary to octal.

Hexadecimal no. AB. CD

Binary equivalent 1010 1011 1100 1101

A B C D

To convert in octal group three binary digits together as shown

010 101 011 110 011 010

2 5 3 6 3 2

So, $(AB.CD)_{\text{H}} = (253.632)_8$

SOL 1.8.54 Option (B) is correct.

In a 555 astable multi vibrator circuit, charging of capacitor occurs through resistor $(R_A + R_B)$ and discharging through resistor R_B only. Time for charging and discharging is given as.

$$T_C = 0.693(R_A + R_B)C = 0.693\,R_B C$$

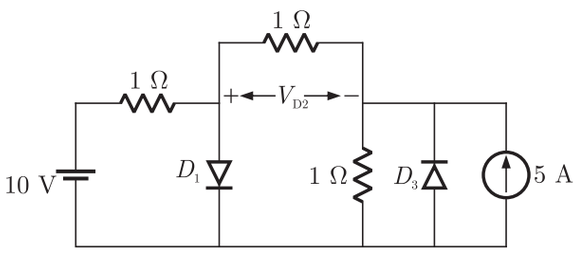
But in the given circuit the diode will go in the forward bias during charging, so the capacitor will charge through resistor R_A only and discharge through R_B only.

a $R_A = R_B$

So $T_C = T_D$

SOL 1.8.55 Option (A) is correct.

First we can check for diode D_2. Let diode D_2 is OFF then the circuit is



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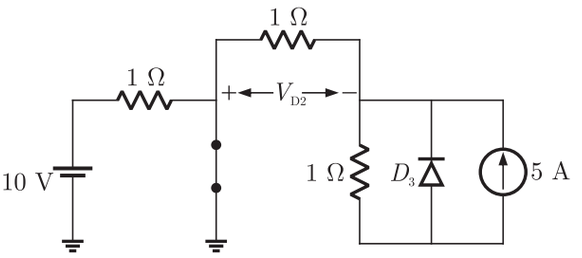
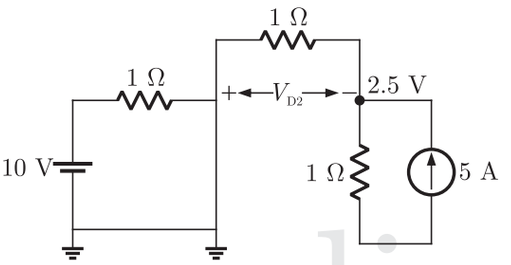
In the above circuit diode D_1 must be ON, as it is connected with 10 V battery now the circuit is



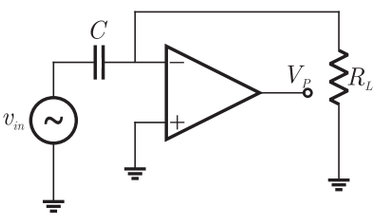
Because we assumed diode D_2 OFF so voltage across it $V_{D2} \neq 0$ and it is possible only when D_3 is off.



So, all assumptions are true.

SOL 1.8.56 Option (D) is correct.

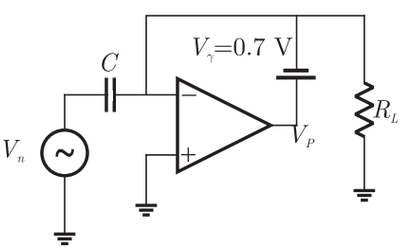
In the positive half cycle of input, Diode D_1 will be reverse biased and equivalent circuit is.



Since there is no feed back to the op-amp and op-amp has a high open loop gain so it goes in saturation. Input is applied at inverting terminal so.

$$V_P = -V_{CC} = -12 \text{ V}$$

In negative half cycle of input, diode D_1 is in forward bias and equivalent circuit is shown below.



Output $V_P = V_\gamma + V_-$

Op-amp is at virtual ground so $V_+ = V_- = 0$ and $V_P = V_\gamma = 0.7$ V

Voltage wave form at point P is

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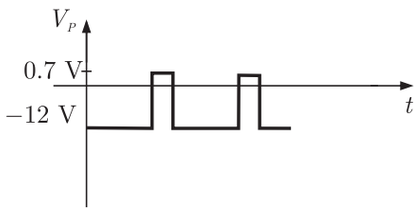
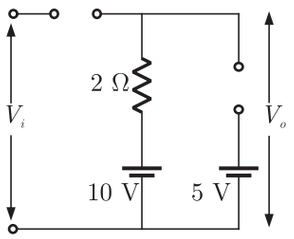


SOL 1.8.57 Option (A) is correct.

In the circuit when $V_i < 10$ V, both D_1 and D_2 are off.

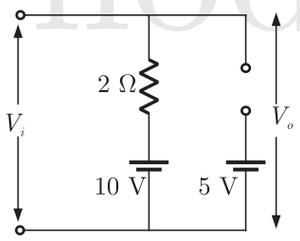
So equivalent circuit is,



Output, $V_o = 10$ volt

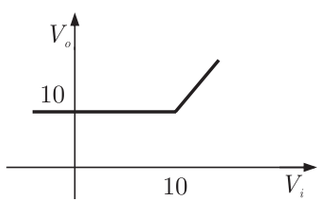
When $V_i > 10$ V (D_1 is in forward bias and D_2 is off

So the equivalent circuit is,



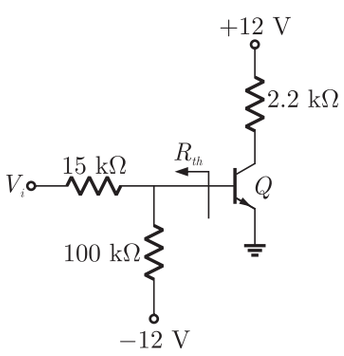
Output, $V_o = V_i$

Transfer characteristic of the circuit is



SOL 1.8.58 Option (B) is correct.

Assume that BJT is in active region, thevenin equivalent of input circuit is obtained as



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$$\frac{V_{th}-V_i}{15}+\frac{V_{th}-(-12)}{100}=0$$

$$20V_{th}-20V_i+3V_{th}+36=0$$

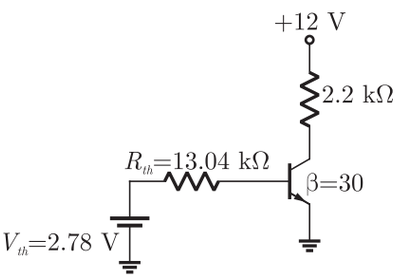
$$23V_{th}=20\times 5-36,\ V_i=5\ \text{V}$$

$$V_{th}=2.78\ \text{V}$$

Thevenin resistance $R_{th}=15\,\text{K}\Omega\,||\,100\,\text{K}\Omega$

$$=13.04\,\text{K}\Omega$$

So the circuit is



Writing KVL for input loop

$$2.78-R_{th}I_B-0.7=0$$

$$I_B=0.157\ \text{mA}$$

Current in saturation is given as,

$$I_{B(\text{sat})}=\frac{I_{C(\text{sat})}}{\beta}$$

$$I_{C(\text{sat})}=\frac{12.2}{2.2}=5.4\ \text{mA}$$

So, $$I_{B(\text{sat})}=\frac{5.45\,\text{mA}}{30}=0.181\ \text{mA}$$

Since $I_{B(\text{sat})}>I_B$, therefore assumption is true.

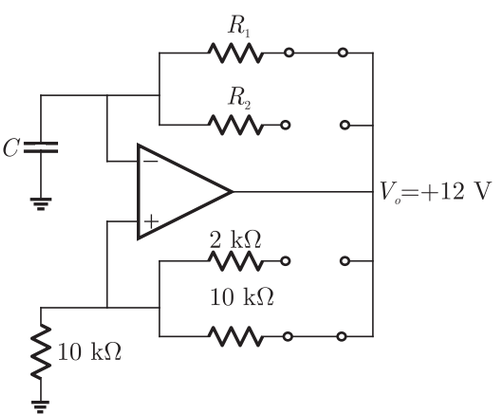
SOL 1.8.59 Option (C) is correct.

Here output of the multi vibrator is

$$V_0=\pm\ 12\ \text{volt}$$

Threshold voltage at positive terminal of op-amp can be obtained as following

When output $V_0=+12$ V, equivalent circuit is,



writing node equation at positive terminal of op-amp

$$\frac{V_{th}-12}{10}+\frac{V_{th}-0}{10}=0$$

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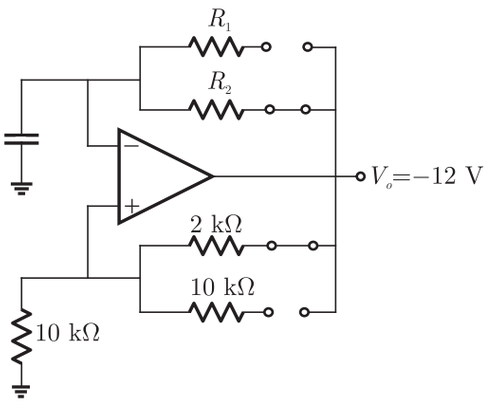
$$V_{th} = 6 \text{ volt} \quad \text{(Positive threshold)}$$

So, the capacitor will charge upto 6 volt.

When output $V_0 = -12$ V, the equivalent circuit is.



node equation

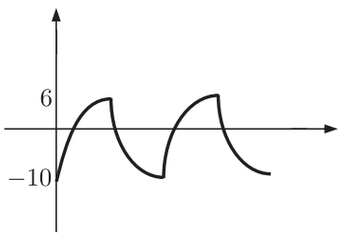
$$\frac{V_{th}+12}{2}+\frac{V_{th}-0}{10}=0$$

$$5\,V_{th}+60+V_{th}=0$$

$$V_{th} = -10 \text{ volt} \quad \text{(negative threshold)}$$

So the capacitor will discharge upto -10 volt.

At terminal P voltage waveform is.



SOL 1.8.60 Option () is correct.

SOL 1.8.61 Option () is correct.

SOL 1.8.62 Option (A) is correct.

Function F can be obtain as,

$$\begin{aligned} F &= I_0\overline{S}_1\overline{S}_0 + I_1\overline{S}_1 S_0 + I_2 S_1\overline{S}_0 + I_3 S_1 S_0 \\ &= A\overline{B}\,\overline{C} + \overline{A}\,\overline{B}\,C + 1\$B\overline{C} + 0\$BC \\ &= A\overline{B}\,\overline{C} + \overline{A}\,\overline{B}C + B\overline{C} \;= A\overline{B}\,\overline{C} + \overline{A}\,\overline{B}C + B\overline{C}(A+\overline{A}) \\ &= A\overline{B}\,\overline{C} + \overline{A}\,\overline{B}C + AB\overline{C} + \overline{A}\,B\overline{C} \\ &= \Sigma(1,2,4,6) \end{aligned}$$

SOL 1.8.63 Option (A) is correct.

MVI H and MVI L stores the value 255 in H and L registers. DCR L decrements L by 1 and JNZ checks whether the value of L is zero or not. So DCR L executed 255 times till value of L becomes '0'.

Then DCR H will be executed and it goes to 'Loop' again, since L is of 8 bit so no more decrement possible and it terminates.

SOL 1.8.64 Option (A) is correct.

XCHG &Exchange the contain of DE register pair with HL pair So now addresses of memory locations are stored in HL pair.

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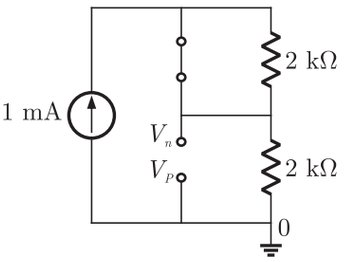
INR M & Increment the contents of memory whose address is stored in HL pair.

SOL 1.8.65 Option (A) is correct.

From the circuit we can observe that Diode D_1 must be in forward bias (since current is flowing through diode).

Let assume that D_2 is in reverse bias, so equivalent circuit is.



Voltage V_n is given by

$$V_n = 1 \,\#\, 2 = 2 \text{ Volt}$$

$$V_p = 0$$

$V_n > V_p$ (so diode is in reverse bias, assumption is true)

Current through D_2 is $I_{D2} = 0$

SOL 1.8.66 Option (C) is correct.

SHLD transfers contain of HL pair to memory location.

SHLD 2050 & L " M[2050H]

H " M[2051H]

SOL 1.8.67 Option (D) is correct.

This is a N-channel MOSFET with $V_{GS} = 2\,\text{V}$

$$V_{TH} = +1\,\text{V}$$

$$V_{DS(\text{sat})} = V_{GS} - V_{TH}$$

$$V_{DS(\text{sat})} = 2 - 1 = 1 \text{ V}$$

Due to 10 V source $V_{DS} > V_{DS(\text{sat})}$ so the NMOS goes in saturation, channel conductivity is high and a high current flows through drain to source and it acts as a short circuit.

So, $V_{ab} = 0$

SOL 1.8.68 Option (C) is correct.

Let the present state is Q(t), so input to D-flip flop is given by,

$$D = Q(t) \,\#\, X$$

Next state can be obtained as,

$$\begin{aligned} Q(t+1) &= D \\ &= Q(t) \,\#\, X \\ &= Q(t)\overline{X} + \overline{Q}(t)X \\ &= \overline{Q}(t), \quad \text{if } X = 1 \end{aligned}$$

and $Q(t+1) = Q(t), \quad \text{if } X = 0$

So the circuit behaves as a T flip flop.

SOL 1.8.69 Option (B) is correct.

Since the transistor is operating in active region.

$$I_E \;.\; \beta I_B$$

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$$I_B = \frac{I_E}{\beta} = \frac{1\text{ mA}}{100} = 10\,\mu\text{A}$$

SOL 1.8.70 Option (C) is correct.

Gain of the inverting amplifier is given by,

$$A_v = -\frac{R_F}{R_1} = -\frac{1\,\#\,10^6}{R_1}, \quad R_F = 1\ \ \text{M}\Omega$$

$$R_1 = -\frac{1\,\#\,10^6}{A_v}$$

$A_v = -10$ to -25 so value of R_1

$$R_1 = \frac{10^6}{10} = 100\,\text{k}\Omega \qquad \text{for } A_v = -10$$

$$R_1' = \frac{10^6}{25} = 40\,\text{k}\Omega \qquad \text{for } A_v = -25$$

R_1 should be as large as possible so $R_1 = 100\,\text{k}\Omega$

SOL 1.8.71 Option (B) is correct.

Direct coupled amplifiers or DC-coupled amplifiers provides gain at dc or very low frequency also.

SOL 1.8.72 Option (C) is correct.

Since there is no feedback in the circuit and ideally op-amp has a very high value of open loop gain, so it goes into saturation (ouput is either $+V$ or $-V$) for small values of input.

The input is applied to negative terminal of op-amp, so in positive half cycle it saturates to $-V$ and in negative half cycle it goes to $+V$.

SOL 1.8.73 Option (B) is correct.

CHECK From the given input output waveforms truth table for the circuit is drawn as

X_1	X_2	Q
1	0	1
0	0	1
0	1	0

In option (A), for $X_1 = 1, Q = 0$ so it is eliminated.

In option (C), for $X_1 = 0, Q = 0$ (always), so it is also eliminated.

In option (D), for $X_1 = 0, Q = 1$, which does not match the truth table.

Only option (B) satisfies the truth table.

SOL 1.8.74 Option (D) is correct.

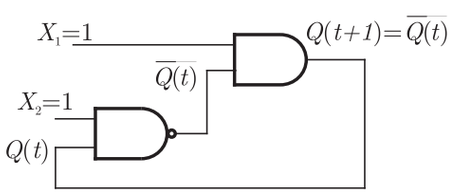
In the given circuit NMOS Q_1 and Q_3 makes an inverter circuit. Q_4 and Q_5 are in parallel works as an OR circuit and Q_2 is an output inverter.

So output is

$$Q = \overline{\overline{X_1} + X_2} = X_1.\overline{X_2}$$

SOL 1.8.75 Option (D) is correct.

Let $Q(t)$ is the present state then from the circuit,



So, the next state is given by

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$$Q(t+1) = \overline{Q}(t) \text{ (unstable)}$$

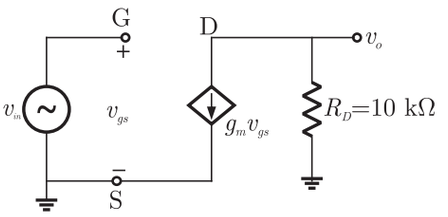
SOL 1.8.76 Option (B) is correct.

Trans-conductance of MOSFET is given by

$$g_m = \frac{2i_D}{2V_{GS}}$$
$$= \frac{(2-1)\text{ mA}}{(2-1)\text{ V}} = 1 \text{ mS}$$

SOL 1.8.77 Option (D) is correct.

Voltage gain can be obtain by small signal equivalent circuit of given amplifier.



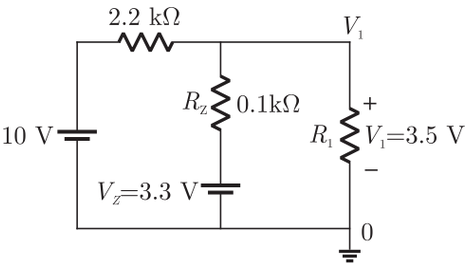
$$v_o = -g_m v_{gs} R_D$$
$$v_{gs} = v_{in}$$

So, $$v_o = -g_m R_D v_{in}$$

Voltage gain $$A_v = \frac{v_o}{v_i} = -g_m R_D$$
$$= -(1\text{ mS})(10\text{ k}\Omega) = -10$$

SOL 1.8.78 Option (C) is correct.

Given circuit,



In the circuit

$$V_1 = 3.5 \text{ V (given)}$$

Current in zener is.

$$I_Z = \frac{V_1 - V_Z}{R_Z} = \frac{3.5 - 3.3}{0.1 \# 10^3} = 2\text{ mA}$$

SOL 1.8.79 Option (C) is correct.

This is a current mirror circuit. Since V_{BE} is the same in both devices, and transistors are perfectly matched, then

$$I_{B1} = I_{B2} \text{ and } I_{C1} = I_{C2}$$

From the circuit we have,

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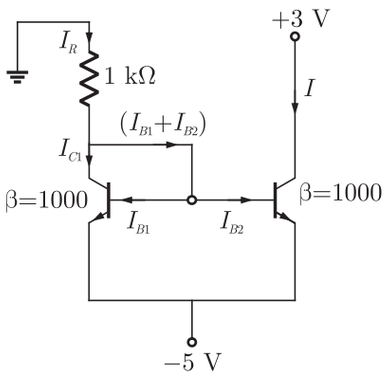


$$I_R = I_{C1} + I_{B1} + I_{B2} = I_{C1} + 2I_{B2} \qquad \because I_{B1} = I_{B2}$$

$$= I_{C2} + \frac{2I_{C2}}{\beta} \qquad \because I_{C1} = I_{C2}, I_{C2} = \beta I_{B2}$$

$$I_R = I_{C2}\left(1 + \frac{2}{\beta}\right)$$

$$I_{C2} = I = \frac{I_R}{\left(1 + \frac{2}{\beta}\right)}$$

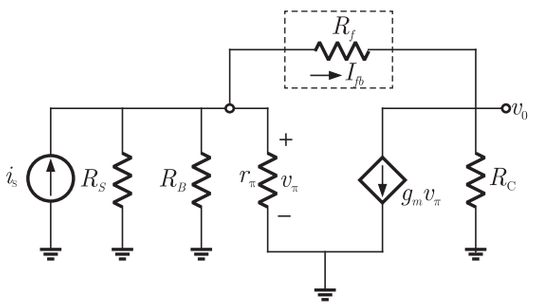
I_R can be calculate as

$$I_R = \frac{-5 + 0.7}{1 \# 10^3} = -4.3 \text{ mA}$$

So,
$$I = \frac{4.3}{\left(1 + \frac{2}{100}\right)} \text{ - } 4.3 \text{ mA}$$

SOL 1.8.80 Option (B) is correct.

The small signal equivalent circuit of given amplifier



Here the feedback circuit samples the output voltage and produces a feed back current I_{fb} which is in shunt with input signal. So this is a shunt-shunt feedback configuration.

SOL 1.8.81 Option (A) is correct.

In the given circuit output is stable for both 1 or 0. So it is a bistable multi-vibrator.

SOL 1.8.82 Option (A) is correct.

Since there are two levels ($+V_{CC}$ *or* $-V_{CC}$) of output in the given comparator circuit.

For an n-bit Quantizer

$$2^n = \text{No. of levels}$$

$$2^n = 2$$

$$n = 1$$

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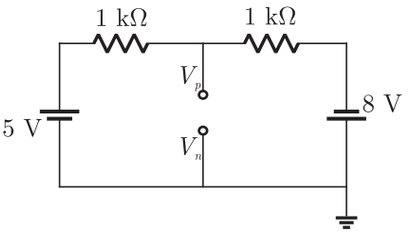
SOL 1.8.83 Option (C) is correct.

From the circuit, we can see the that diode D_2 must be in forward Bias.

For D_1 let assume it is in reverse bias.

Voltages at p and n terminal of D_1 is given by V_p and V_n

$V_p < V_n$ (D_1 is reverse biased)



Applying node equation

$$\frac{V_p - 5}{1} + \frac{V_p + 8}{1} = 0$$

$$2V_p = -3$$

$$V_p = -1.5$$

$$V_n = 0$$

$V_p < V_n$ (so the assumption is true and D_1 is in reverse bias) and current in D_1

$$I_{D1} = 0 \text{ mA}$$

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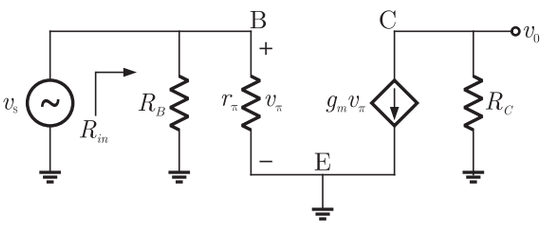
SOL 1.8.84 Option (D) is correct.

The small signal ac equivalent circuit of given amplifier is as following.



Here $R_B = (10\ \text{k}\Omega \lessdot 10\ \text{k}\Omega) = 5\ \text{k}\Omega$

$g_m = 10\ \text{ms}$

$g_m r_\pi = \beta$ & $r_\pi = \dfrac{50}{10 \# 10^{-3}} = 5\ \text{k}\Omega$

Input resistance

$$R_{in} = R_B \lessdot r_\pi = 5\ \text{k}\Omega \lessdot 5\ \text{k}\Omega = 2.5\ \text{k}\Omega$$

SOL 1.8.85 Option (D) is correct.

For PMOS to be biased in non-saturation region.

$$V_{SD} < V_{SD(\text{sat})}$$

and

$$V_{SD(\text{sat})} = V_{SG} + V_T$$

$$V_{SD(\text{sat})} = 4 - 1 \qquad \{\because\ V_{SG} = 4 - 0 = 4 \text{ volt}$$

$$= 3 \text{ Volt}$$

So, $V_{SD} < 3$

$$V_S - V_D < 3$$

$$4 - I_D R < 3$$

$$1 < I_D R$$

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$$I_D R > 1, \qquad I_D = 1 \text{ mA}$$
$$R > 1000\ \Omega$$

SOL 1.8.86 Option () is correct.

SOL 1.8.87 Option (B is correct.

If op-amp is ideal, no current will enter in op-amp. So current i_x is

$$i_x = \frac{v_x - v_y}{1 \# 10^6} \qquad ...(1)$$
$$v_+ = v_- = v_x \qquad \text{(ideal op-amp)}$$

$$\frac{v_x - v_y}{100 \# 10^3} + \frac{v_x - 0}{10 \# 10^3} = 0$$
$$v_x - v_y + 10v_x = 0$$
$$11v_x = v_y \qquad ...(2)$$

For equation (1) & (2)

$$i_x = \frac{v_x - 11v_x}{1 \# 10^6} = -\frac{10v_x}{10^6}$$

Input impedance of the circuit.

$$R_{in} = \frac{v_x}{i_x} = -\frac{10^6}{10} = -100\ \text{k}\Omega$$

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SOL 1.8.88 Option (A) is correct.

Given Boolean expression,

$$\begin{aligned} Y &= (\overline{A} \$ BC + D)(\overline{A} \$ D + \overline{B} \$ \overline{C}) \\ &= (\overline{A} \$ BCD) + (\overline{A}BC \$ \overline{B} \$ \overline{C}) + (\overline{A}D) + \overline{B}\,\overline{C}D \\ &= \overline{A}\,BCD + \overline{A}D + \overline{B}\,\overline{C}\,D \\ &= \overline{A}D(BC + 1) + \overline{B}\,\overline{C}D = \overline{A}D + \overline{B}\,\overline{C}\,D \end{aligned}$$

SOL 1.8.89 Option (D) is correct.

In the given circuit, output is given as.

$$Y = (A_0 \mathbf{5} B_0) \mathbf{9} (A_1 \mathbf{5} B_1) \mathbf{9} (A_2 \mathbf{5} B_2) \mathbf{9} (A_3 \mathbf{5} B_3)$$

For option (A)

$$\begin{aligned} Y &= (1 \mathbf{5} 1) \mathbf{9} (0 \mathbf{5} 0) \mathbf{9} (1 \mathbf{5} 1) \mathbf{9} (0 \mathbf{5} 0) \\ &= 0 \mathbf{9} 0 \mathbf{9} 0 \mathbf{9} 0 = 1 \end{aligned}$$

For option (B)

$$\begin{aligned} Y &= (0 \mathbf{5} 0) \mathbf{9} (1 \mathbf{5} 1) \mathbf{9} (0 \mathbf{5} 0) \mathbf{9} (1 \mathbf{5} 1) \\ &= 0 \mathbf{9} 0 \mathbf{9} 0 \mathbf{9} 0 = 1 \end{aligned}$$

For option (C)

$$\begin{aligned} Y &= (0 \mathbf{5} 0) \mathbf{9} (0 \mathbf{5} 0) \mathbf{9} (1 \mathbf{5} 1) \mathbf{9} (0 \mathbf{5} 0) \\ &= 0 \mathbf{9} 0 \mathbf{9} 0 \mathbf{9} 0 = 1 \end{aligned}$$

For option (D)

$$\begin{aligned} Y &= (1 \mathbf{5} 1) \mathbf{9} (0 \mathbf{5} 0) \mathbf{9} (1 \mathbf{5} 1) \mathbf{9} (0 \mathbf{5} 1) \\ &= 0 \mathbf{9} 0 \mathbf{9} 0 \mathbf{9} 1 = 0 \end{aligned}$$

SOL 1.8.90 Option (B) is correct.

In the given circuit, waveforms are given as,

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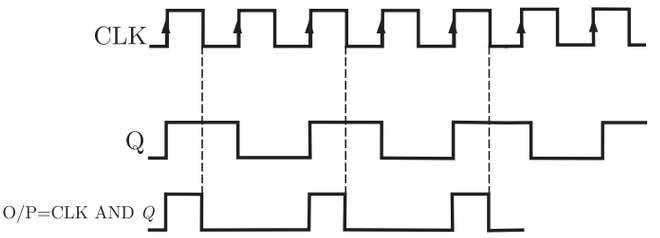


SOL 1.8.91 Option (C) is correct.

The program is executed in following steps.

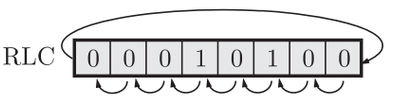
START MVI A, 14H " one instruction cycle.

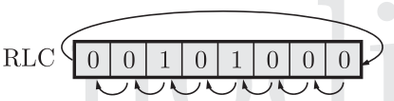
RLC ⇒ rotate accumulator left without carry

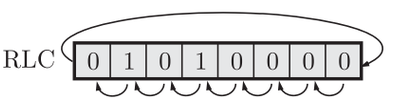
RLC is executed 6 times till value of accumulator becomes zero.

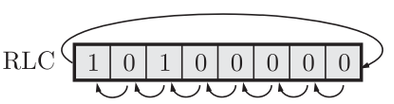
JNZ, JNZ checks whether accumulator value is zero or not, it is executed 5 times.

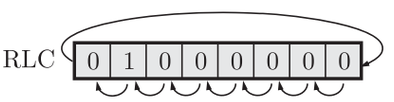
HALT " 1-instruction cycle.

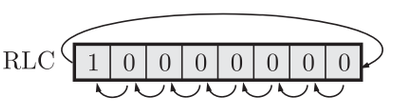


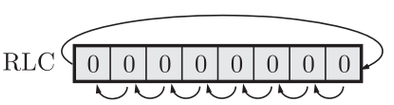












So total no. of instruction cycles are

$$n = 1 + 6 + 5 + 1$$
$$= 13$$

SOL 1.8.92 Option (B) is correct.

In the given circuit

$$V_i = 0 \text{ V}$$

So, transistor Q_1 is in cut-off region and Q_2 is in saturation.

$$5 - I_C R_C - V_{CE(\text{sat})} - 1.25 = 0$$

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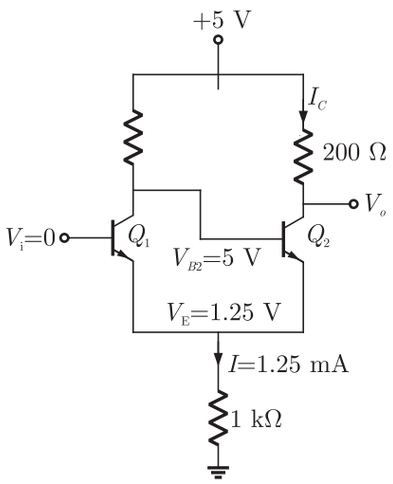
$$5 - I_C R_C - 0.1 - 1.25 = 0$$
$$5 - I_C R_C = 1.35$$
$$V_0 = 1.35 \qquad \text{"a } V_0 = 5 - I_C R_C$$



SOL 1.8.93 Option (C) is correct.

Since there exists a drain current for zero gate voltage ($V_{GS} = 0$), so it is a depletion mode device.

I_D increases for negative values of gate voltages so it is a p-type depletion mode device.

SOL 1.8.94 Option (B) is correct.

Applying KVL in input loop,

$$4 - (33 \# 10^3) I_B - V_{BE} - (3.3 \# 10^3) I_E = 0 \qquad \text{a } I_E = (h_{fe} + 1) I_B$$
$$4 - (33 \# 10^3) I_B - 0.7 - (3.3 \# 10^3)(h_{fe} + 1) I_B = 0$$
$$3.3 = [(33 \# 10^3) + (3.3 \# 10^3)(99 + 1)] I_B$$
$$I_B = \frac{3.3}{33 \# 10^3 + 3.3 \# 10^3 \# 100}$$
$$I_C = h_{fe} I_B$$
$$= \frac{99 \# 3.3}{[0.33 + 3.3] \# 100} \text{ mA} = \frac{3.3}{0.33 + 3.3} \text{ mA}$$

SOL 1.8.95 Option (D) is correct.

Let the voltages at positive and negative terminals of op-amp are v_+ and v_- respectively. Then by applying nodal equations.

$$\frac{v_- - v_{in}}{R_1} + \frac{v_- - v_{out}}{R_1} = 0$$
$$2v_- = v_{in} + v_{out} \qquad ..(1)$$

Similarly,

$$\frac{v_+ - v_{in}}{R} + \frac{v_+ - 0}{\left[\frac{1}{j\omega C}\right]} = 0$$
$$v_+ - v_{in} + v_+(j\omega CR) = 0$$
$$v_+(1 + j\omega CR) = V_{in} \qquad ..(2)$$

By equation (1) & (2)

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$$\frac{2v_{in}}{1+j\omega CR} = v_{in} + v_{out} \qquad \because\ v_+ = v_- \text{ (ideal op-amp)}$$

$$v_{in}\left(\frac{2}{1+j\omega CR} - 1\right) = v_{out}$$

$$v_{out} = v_{in}\frac{(1-j\omega CR)}{1+j\omega CR}$$

Phase shift in output is given by

$$\theta = \tan^{-1}(-\omega CR) - \tan^{-1}(\omega CR)$$
$$= \pi - \tan^{-1}(\omega CR) - \tan^{-1}(\omega CR)$$
$$= \pi - 2\tan^{-1}(\omega CR)$$

Maximum phase shift $\theta = \pi$

SOL 1.8.96 Option (C) is correct.

In given circuit MUX implements a 1-bit full adder, so output of MUX is given by.

$$F = \text{Sum} = A \oplus Q \oplus C_{in}$$

Truth table can be obtain as.

P	Q	C_{in}	Sum
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

$$\text{Sum} = \overline{P}\,\overline{Q}\,C_{in} + \overline{P}Q\,\overline{C_{in}} + P\,\overline{Q}\,\overline{C_{in}} + P\,Q\,C_{in}$$

Output of MUX can be written as

$$F = \overline{P}\,\overline{Q}\,I_0 + \overline{P}Q\,I_1 + P\overline{Q}\,I_2 + PQ\,I_3$$

Inputs are,

$$I_0 = C_{in},\quad I_1 = \overline{C_{in}},\quad I_2 = \overline{C_{in}},\quad I_3 = C_{in}$$

SOL 1.8.97 Option (D) is correct.

Program counter contains address of the instruction that is to be executed next.

SOL 1.8.98 Option (A) is correct.

For a n-channel enhancement mode MOSFET transition point is given by,

$$V_{DS(\text{sat})} = V_{GS} - V_{TH} \qquad \because\ V_{TH} = 2\text{ volt}$$
$$V_{DS(\text{sat})} = V_{GS} - 2$$

From the circuit,

$$V_{DS} = V_{GS}$$

So $$V_{DS(\text{sat})} = V_{DS} - 2 \quad \& \quad V_{DS} = V_{DS(\text{sat})} + 2$$
$$V_{DS} > V_{DS(\text{sat})}$$

Therefore transistor is in saturation region and current equation is given by.

$$I_D = K(V_{GS} - V_{TH})^2$$
$$4 = K(V_{GS} - 2)^2$$

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V_{GS} is given by

$$V_{GS} = V_{DS} = 10 - I_D R_D = 10 - 4 \# 1 = 6 \text{ Volt}$$

So,
$$4 = K(6-2)^2$$
$$K = \frac{1}{4}$$

Now R_D is increased to 4 kΩ, Let current is $I_D^{'}$ and voltages are $V_{DS}^{'} = V_{GS}^{'}$

Applying current equation.

$$I_D^{'} = K(V_{GS}^{'} - V_{TH})^2$$
$$I_D^{'} = \frac{1}{4}(V_{GS}^{'} - 2)^2$$
$$V_{GS}^{'} = V_{DS}^{'} = 10 - I_D^{'} \# R_D^{'} = 10 - 4I_D^{'}$$

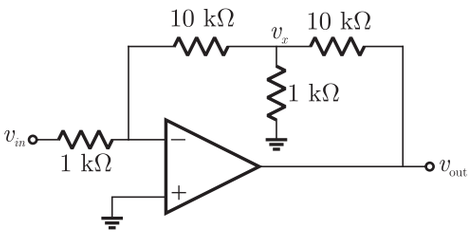
So,

$$4I_D^{'} = (10 - 4I_D^{'} - 2)^2 = (8 - 4I_D^{'})^2$$
$$= 16(2 - I_D^{'})^2$$
$$I_D^{'} = 4(4 + I'^2_D - 4I_D^{'})$$
$$4I'^2_D - 17 + 16 = 0$$
$$I'^2_D = 2.84 \text{ mA}$$

SOL 1.8.99 Option (D) is correct.

Let the voltages at input terminals of op-amp are v_- and v_+ respectively.

So, $v_+ = v_- = 0$ (ideal op-amp)



Applying node equation at negative terminal of op-amp,

$$\frac{0 - v_{in}}{1} + \frac{0 - v_x}{10} = 0 \qquad \ldots(1)$$

At node x

$$\frac{v_x - 0}{10} + \frac{v_x - v_{out}}{10} + \frac{v_x - 0}{1} = 0$$
$$v_x + v_x - v_{out} + 10v_x = 0$$
$$12\,v_x = v_{out}$$
$$v_x = \frac{v_{out}}{12}$$

From equation (1),
$$\frac{v_{in}}{1} + \frac{v_x}{10} = 0$$
$$v_{in} = -\frac{v_{out}}{120}$$
$$\frac{v_{out}}{v_{in}} = -120$$

SOL 1.8.100 Option (D) is correct.

In the positive half cycle (when $V_{in} > 4$ V) diode D_2 conducts and D_1 will be off so the equivalent circuit is,

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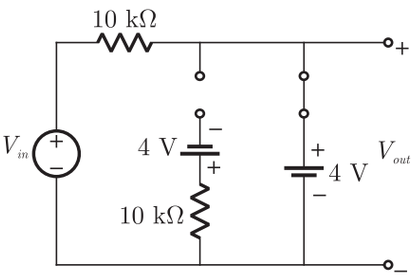
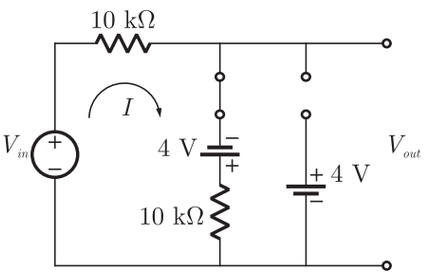


$$V_{out} = +4 \text{ Volt}$$

In the negative half cycle diode D_1 conducts and D_2 will be off so the circuit is,



Applying KVL

$$V_{in} - 10I + 4 - 10I = 0$$

$$\frac{V_{in} + 4}{20} = I$$

$V_{in} = -10$ V (Maximum value in negative half cycle)

So,
$$I = \frac{-10+4}{20} = -\frac{3}{10} \text{ mA}$$

$$\frac{V_{in} - V_{out}}{10} = I$$

$$\frac{-10 - V_{out}}{10} = -\frac{3}{10}$$

$$V_{out} = -(10-3)$$

$$V_{out} = -7 \text{ volt}$$

SOL 1.8.101 Option (C) is correct.

In the circuit, the capacitor charges through resistor $(R_A + R_B)$ and discharges through R_B. Charging and discharging time is given as.

$$T_C = 0.693(R_A + R_B)\,C$$

$$T_D = 0.693\,R_B\,C$$

Frequency $f = \frac{1}{T} = \frac{1}{T_D + T_C} = \frac{1}{0.693(R_A + 2R_B)C}$

$$\frac{1}{0.693(R_A + 2R_B) \# 10 \# 10^{-9}} = 10 \# 10^3$$

$$14.4 \# 10^3 = R_A + 2R_B \quad \ldots(1)$$

$$\text{duty cycle} = \frac{T_C}{T} = 0.75$$

$$\frac{0.693(R_A + R_B)C}{0.693(R_A + 2R_B)C} = \frac{3}{4}$$

$$4R_A + 4R_B = 3R_A + 6R_B$$

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$$R_A = 2R_B \quad \ldots(2)$$

From (1) and (2)

$$2R_A = 14.4 \# 10^3$$

$$R_A = 7.21\ \text{k}\Omega$$

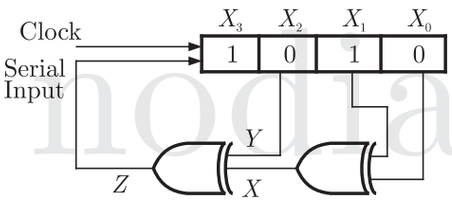
and $$R_B = 3.60\ \text{k}\Omega$$

SOL 1.8.102 Option (B) is correct.

Given boolean expression can be written as,

$$\begin{aligned} F &= \overline{X}Y\overline{Z} + \overline{X}\,\overline{Y}Z + X\overline{Y}Z + XY\overline{Z} + XYZ \\ &= \overline{X}\,YZ + \overline{Y}Z(X + \overline{X}) + XY(\overline{Z} + Z) \\ &= \overline{X}Y\overline{Z} + \overline{Y}Z + XY \\ &= \overline{Y}Z + Y(X + \overline{X}\,\overline{Z}) \quad \textbf{a}\ \ A + BC = (A + B)(A + C) \\ &= \overline{Y}Z + Y(X + \overline{X})(X + \overline{Z}) \\ &= \overline{Y}Z + Y(X + \overline{Z}) \\ &= \overline{Y}Z + YX + Y\overline{Z} \end{aligned}$$

SOL 1.8.103 Option (B) is correct.



$$X = X_1 \oplus X_0,\ Y = X_2$$

Serial Input $Z = X$ **5** $Y = [X_1$ **5** $X_0]$ **5** X_2

Truth table for the circuit can be obtain as.

Clock pulse	Serial Input	Shift register
Initially	1	1010
1	0	1101
2	0	0110
3	0	0011
4	1	0001
5	0	1000
6	1	0100
7	1	1010

So after 7 clock pulses contents of the shift register is 1010 again.

SOL 1.8.104 Option (D) is correct.

Characteristic table of the X-Y flip flop is obtained as.

X	Y	Q_n	Q_{n+1}
0	0	0	1
0	0	1	1
0	1	0	0
0	1	1	1

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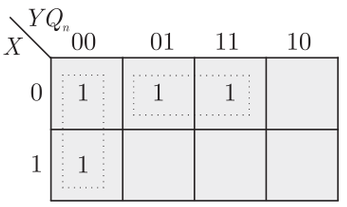
1	0	0	1
1	0	1	0
1	1	0	0
1	1	0	0

Solving from k-map



Characteristic equation of X-Y flip flop is

$$Q_{n+1} = \overline{Y}\ \overline{Q_n} + \overline{X} Q_n$$

Characteristic equation of a J-K flip-flop is given by

$$Q_{n+1} = \overline{K} Q_n + J\ \overline{Q_n}$$

by comparing above two characteristic equations

$$J = \overline{Y},\ K = X$$

SOL 1.8.105 Option (A) is correct.

Total size of the memory system is given by.

$$= (2^{12} \# 4) \# 8 \text{ bits}$$
$$= 2^{14} \# 8 \text{ bits}$$
$$= 2^{14} \text{ Bytes}$$
$$= 16\,\text{K bytes}$$

SOL 1.8.106 Option (C) is correct.

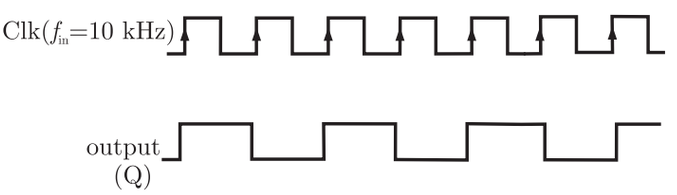
Executing all the instructions one by one.

$$\text{LXI H,1FFE} \Rightarrow \text{H} = (1\text{F})_{\text{H}},\ \ \text{L} = (\text{FE})_{\text{H}}$$
$$\text{MOV B,M \& B} = \text{Memory [HL]} = \text{Memory [1FFE]}$$
$$\text{INR L \& L} = \text{L} + (1)_{\text{H}} = (\text{FF})_{\text{H}}$$
$$\text{MOV A,M \& A} = \text{Memory [HL]} = \text{Memory [1FFF]}$$
$$\text{ADD B \& A} = \text{A} + \text{B}$$
$$\text{INR L \& L} = \text{L} + (1)_{\text{H}} = (\text{FF})_{\text{H}} + (1)_{\text{H}} = 00$$
$$\text{MOV M,A \& Memory [HL]} = \text{A}$$
$$\text{Memory [1F00]} = \text{A}$$
$$\text{XOR A \& A} = \text{A XOR A} = 0$$

So the result of addition is stored at memory address 1F00.

SOL 1.8.107 Option (D) is correct.

Let the initial state Q(t) = 0, So $D = \overline{Q} = 1$, the output waveform is.



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So frequency of the output is,

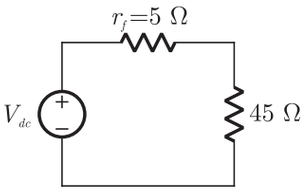
$$f_{out} = \frac{f_{in}}{2} = \frac{10}{2} = 5 \text{ kHz}$$

SOL 1.8.108 Option (A) is correct.

This is a half-wave rectifier circuit, so the DC voltage is given by

$$V_{dc} = \frac{V_m}{\pi}$$

Equivalent circuit with forward resistance is



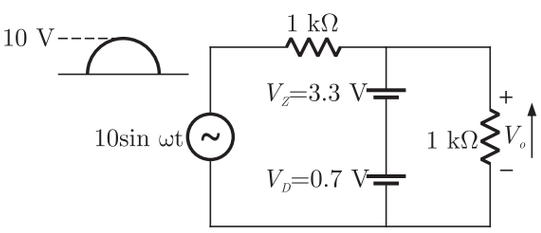
DC current in the circuit

$$I_{dc} = \frac{\frac{V_m}{\pi}}{r_f + R} = \frac{(V_m/\pi)}{(5+45)}$$

$$I_{dc} = \frac{V_m}{50\pi}$$

SOL 1.8.109 Option (B) is correct.

In the positive half cycle zener diode (D_z) will be in reverse bias (behaves as a constant voltage source) and diode (D) is in forward bias. So equivalent circuit for positive half cycle is.

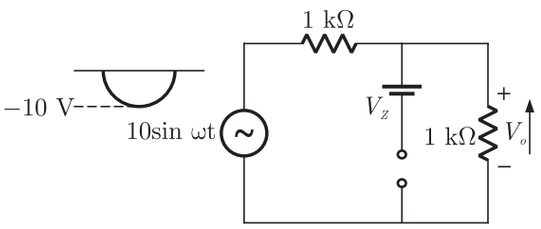


Output $V_o = V_D + V_z$

$= 0.7 + 3.3$

$= 4$ Volt

In the negative halt cycle, zener diode (D_z) is in forward bias and diode (D) is in reverse bias mode. So equivalent circuit is.



So the peak output is,

$$V_o = \frac{10}{(1+1)} \# 1$$

$$V_o = 5 \text{ Volt}$$

SOL 1.8.110 Option (A) is correct.

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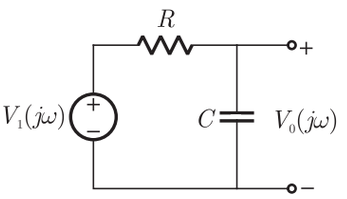
For active low chip select $\overline{CS} = 0$, so the address range can be obtain as,

$A_{15}A_{14}A_{13}A_{12}$	$A_{11}A_{10}A_9A_8$	$A_7A_6A_5A_4$	$A_3A_2A_1A_0$
1110	0000	0000	0000
h	h	h	h
1110	1111	1111	1111

So address range is E000-EFFF

SOL 1.8.111 Option (C) is correct.

A first order low pass filter is shown in following figure.



Transfer function

$$H(j\omega) = \frac{V_0(j\omega)}{V_1(j\omega)} = \frac{1}{R + \frac{1}{j\omega C}} \# \frac{1}{j\omega C} = \frac{1}{j\omega cR + 1}$$

Given that $|H(j\omega_1)| = 0.25$

$$\frac{1}{\sqrt{\omega_1^2 C^2 R^2 + 1}} = \frac{1}{4}$$

$$16 = \omega_1^2 R^2 C^2 + 1$$

$$\omega_1^2 R^2 C^2 = 15$$

$$4\pi^2 f_1^2 (50)^2 (5 \# 10^{-6})^2 = 15$$

$$f_1 = 2.46 \text{ kHz}$$

SOL 1.8.112 Option (A) is correct.

In the circuit, voltage at positive terminal of op-amp is given by

$$\frac{v_+ - v_o}{10} + \frac{v_+ - 2}{3} = 0$$

$$3(v_+ - v_o) + 10(v_+ - 2) = 0$$

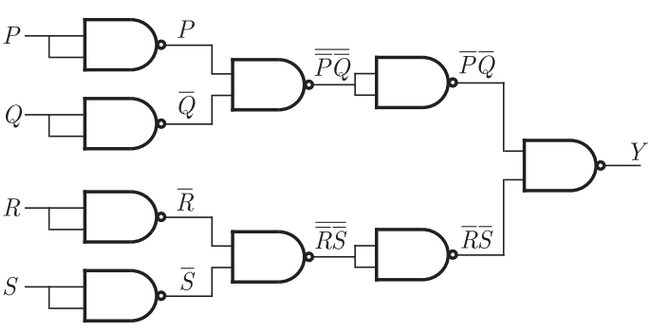
$$13v_+ = 20 + 3v_o$$

Output changes from $+15$ V to -15 V, when $v_- > v_+$

$$v_+ = \frac{20 + (3 \# 15)}{13} = 5 \text{ Volt (for positive half cycle)}$$

SOL 1.8.113 Option (B) is correct.

Output for each stage can be obtain as,



So final output Y is.

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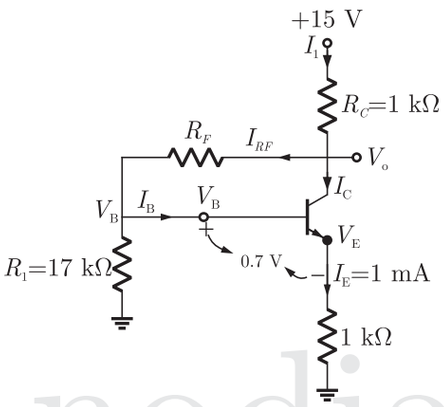
$$Y = \overline{\overline{P\,Q}\,\overline{R\,S}} = \overline{(P+Q)}\,\overline{(R+S)} \qquad \textbf{a}\ \overline{AB} = \overline{A} + \overline{B}$$
$$= P + Q + R + S$$

SOL 1.8.114 Option (B) is correct.

We can analyze that the transistor is in active region.

$$I_C = \frac{\beta}{(\beta+1)} I_E$$
$$= \frac{99}{(99+1)}(1\text{ mA}) = 0.99\text{ mA}$$

In the circuit



In the circuit

$$V_{BE} = 0.7\text{ V}$$
$$V_E = I_E \# 1\text{ k}\Omega \qquad = 1\text{ V}$$

$$V_B - V_E = 0.7$$
$$V_B = 0.7 + 1 = 1.7\text{ volt}$$

Current through R_1

$$I_{R_1} = \frac{V_B}{17\text{ k}\Omega} = \frac{1.7}{17\text{ k}\Omega} = 100\ \mu\text{A}$$
$$I_B = \frac{I_E}{\beta+1} = \frac{1\text{ mA}}{(99+1)} = 10\ \mu\text{A}$$

Current through R_F , by writing KCL at Base

$$I_{RF} = I_B + I_{R1}$$
$$= 10 + 100 = 110\ \mu\text{A}$$

Current through R_C

$$I_1 = I_C + I_{RF}$$
$$= 0.99\text{ mA} + 110\,\mu\text{A} = 1.1\text{ mA}$$

SOL 1.8.115 Option (D) is correct.

Output voltage

$$V_0 = 15 - I_1 R_C$$
$$= 15 - (1.1\text{ mA})(1\text{ k}\Omega) = 13.9\text{ V}$$

SOL 1.8.116 Option (A) is correct.

Current in R_F

$$I_{RF} = \frac{V_0 - V_B}{R_F}$$

$$0.11\text{ mA} = \frac{13.9 - 1.7\text{ k}\Omega}{R_F}$$

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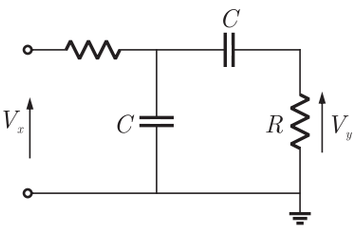
$$R_F = 110.9\,\text{k}\Omega$$

SOL 1.8.117 Option (A) is correct.

By writing node equations in the circuit



$$\frac{V_a - V_x}{R} + V_a Cs + (V_a - V_y) Cs = 0$$

or $$V_a(1 + 2RCs) - V_x - sCRV_y = 0 \quad \ldots(1)$$

or $$(V_y - V_a) Cs + \frac{V_y}{R} = 0$$

or $$V_y(1 + sCR) - V_a sCR = 0 \quad \ldots(2)$$

From equation (1) & (2)

$$\left(\frac{1 + sCR}{sCR}\right)(1 + 2sCR)\,V_y - V_x - sCRV_y = 0$$

$$V_y\left(\frac{(1 + sCR)(1 + 2sCR)}{sCR} - sCR\right) = V_x$$

$$V_y \frac{(1 + 3sCR + 2s^2C^2R^2 - s^2C^2R^2)}{sCR} = V_x$$

Transfer function

$$T(s) = \frac{V_y}{V_x} = \frac{sCR}{1 + 3sCR + s^2C^2R^2}$$

$$T(j\omega) = \frac{j\omega CR}{1 + j3\omega CR - C^2R^2\omega^2} = \frac{j\omega CR}{(1 - C^2R^2\omega^2) + 3j\omega CR}$$

SOL 1.8.118 Option (A) is correct.

Applying Barkhausen criterion of oscillation phase shift will be zero.

$$+T(j\omega_0) = 0 \qquad \omega_0 \text{ " frequency of oscillation.}$$

$$1 - C^2R^2\omega_0^2 = 0$$

$$\omega_0^2 = \frac{1}{R^2C^2}$$

$$\omega_0 = \frac{1}{RC}$$

SOL 1.8.119 Option (C) is correct.

In figure

$$V_y = \frac{V_0}{R_F + R} R$$

$$|T(j\omega)| = \frac{V_y}{V_0} = \left|\frac{j\omega_0 CR}{1 - \omega_0^2 C^2 R^2 + j3\omega_0 CR}\right|$$

$$\omega = \frac{1}{RC}$$

So, $$\frac{V_y}{V_0} = \frac{j}{3j} = \frac{1}{3}$$

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$$\frac{R}{R_F + R} = \frac{1}{3}$$

$$R_F = 2R = 2\,\#\,1 = 2\ \text{k}\Omega$$

SOL 1.8.120 Option (C) is correct.

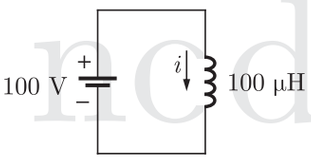
By writing truth table for the circuit

CLK	Q_2	Q_1	Q_0
Initially	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
	1	0	1

All flip flops are reset. When it goes to state 101, output of NAND gate becomes 0 or $\overline{CLR} = 0$, so all FFs are reset. Thus it is modulo 4 counter.

SOL 1.8.121 Option (A) is correct.

When the switch is closed (i.e. during T_{ON}) the equivalent circuit is



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Diode is off during T_{ON}.writing KVL in the circuit.

$$100 - (100 \times 10^{-6})\frac{di}{dt} = 0$$

$$\frac{di}{dt} = 10^6$$

$$i = \int 10^6 dt = 10^6 t + i(0)$$

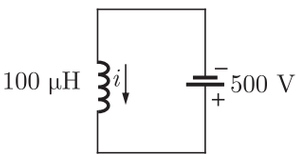
Since initial current is zero $i(0) = 0$

So, $$i = 10^6 t$$

After a duration of T_{ON} the current will be maximum given as

$$i_{\text{Peak}} = 10^6\ T_{ON}$$

When the switch is opened (i.e. during T_{off}) the equivalent circuit is



Diode is ON during T_{off}, writing KVL again

$$500 = -(100 \times 10^{-6})\frac{di}{dt}$$

$$i = -5 \times 10^6 t + i(0)$$

$$i(0) = i_p = 10^6\, T_{ON}$$

So,

$$i = -5 \times 10^6 t + 10^6\ T_{ON}$$

After a duration of T_{off}, current $i = 0$

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So, $0 = -5 \times 10^6 t\, T_{off} + 10^6 T_{ON}$

$\Rightarrow$ $T_{ON} = 5\, T_{off}$

Given that

$$T_{ON} + T_{off} = 100\ \mu sec$$

$$T_{ON} + \frac{T_{ON}}{5} = 100\ \mu sec$$

$$T_{ON} = \frac{100}{1.2} = 63.33\ \mu sec$$

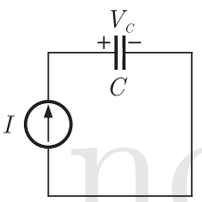
Peak current $i_p = 10^6 \times T_{ON}$

$= 63.33 \times 10^{-6} \times 10^6 = 63.33\ A$

SOL 1.8.122 Option (C) is correct.

When the switch is opened, current flows through capacitor and diode is ON in this condition.

so the equivalent circuit during T_{OFF} is



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$$I = C\frac{dV_c}{dt}$$

$\Rightarrow$ $V_c = \frac{I}{C}t + V_c(0)$

Initially $V_c(0) = 0$

$$V_c = \frac{I}{C}t$$

At $t = T_{off}$

$$V_c = \frac{I}{C}T_{off}$$

Duty cycle $D = \frac{T_{ON}}{T_{ON} + T_{OFF}} = \frac{T_{ON}}{T}$

$$T_{ON} = DT$$

$$T_{OFF} = T - T_{ON} = T - DT$$

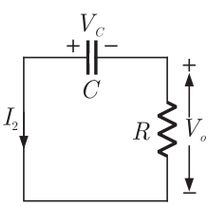
So, $V_c = \frac{I}{C}(T - DT)$

$= \frac{I}{C}(1 - D)\, T$

During T_{OFF}, output voltage $V_0 = 0$ volt.

SOL 1.8.123 Option (B) is correct.

When the switch is closed, diode is off and the circuit is



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In steady state condition

$$C\frac{dV_c}{dt} = I_2$$

$$I_2 = C\frac{I}{C} \qquad \because \frac{dV_c}{dt} = \frac{I}{C}$$

$$V_0 = -V_c = \frac{-I}{C}t$$

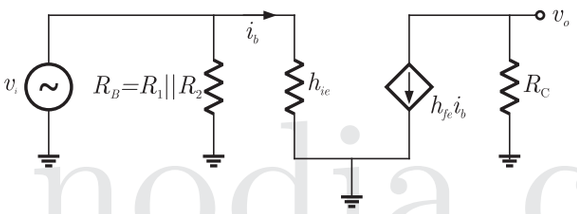
Average output voltage

$$V_0 = \frac{1}{T}\left[\int_0^{DT=T_{ON}}\left(-\frac{I}{C}t\right)dt + \int_0^{T_{OFF}} 0\,dt\right]$$

$$= -\frac{1}{T}.\frac{I}{C}\left[\frac{t^2}{2}\right]_0^{DT} = -\frac{1}{T}.\frac{I}{C}.\frac{D^2T^2}{2} = -\frac{I}{C}\frac{D^2}{2}.T$$

SOL 1.8.124 Option (B) is correct.

Equivalent hybrid circuit of given transistor amplifier when R_E is by passed is shown below.



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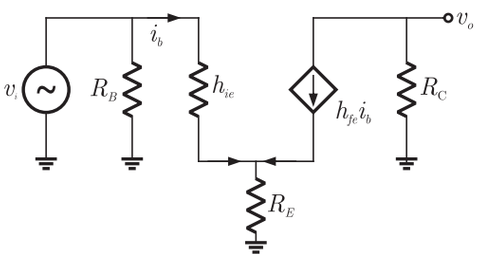
In the circuit

$$i_b = \frac{v_s}{h_{ie}} \qquad ...(1)$$

$$v_o = h_{fe} i_b . R_C = h_{fe} . \frac{v_s}{h_{ie}} . R_C$$

Voltage gain $A_{v_1} = \frac{v_o}{v_i} = \frac{h_{fe} R_C}{h_{ie}}$

Equivalent hybrid circuit when R_E is not bypassed by the capacitor.



In the circuit

$$v_s = i_b h_{ie} + (i_b + h_{fe} i_b) R_E$$

$$v_s = i_b [h_{ie} + (1 + h_{fe}) R_E] \qquad ...(2)$$

$$v_0 = h_{fe} i_b . R_C \qquad ...(3)$$

from equation (2) and (3)

$$v_0 = h_{fe} . R_C \frac{v_s}{h_{ie} + (1 + h_{fe}) R_E}$$

Voltage gain, $A_{v_2} = \frac{v_0}{v_s} = \frac{h_{fe} R_C}{h_{ie} + (1 + h_{fe}) R_E}$

So $$\frac{A_{v_1}}{A_{v_2}} = \frac{h_{ie} + (1 + h_{fe}) R_E}{h_{ie}} = 1 + \frac{(1 + h_{fe}) R_E}{h_{ie}}$$

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$$A_{v_2} < A_{v_1}$$

SOL 1.8.125 Option (C) is correct.

Conversion time for different type of ADC is given as

Counting type T_T " Conversion time

$T_T = 2^n T_C$ T_C " Clock period

Integrating type

$$T_T = 2^{n+1} T_C$$

Successive Approximation type

$$T_T = n T_C$$

Parallel (flash) type " fastest

Conversion time is highest for integrating type ADC. So it is slowest.

SOL 1.8.126 Option (D) is correct.

$$F = \overline{A + B} \text{ (NOR)}$$

Output is 1 when $A = B = 0$

OR, $F = \text{A } \mathbf{9} \text{ B (Ex-NOR)}$

Output is 1 when $A = B = 0$

SOL 1.8.127 Option (B) is correct.

Output of the multiplexer is written as

$$f = I_0\overline{S}_1\overline{S}_0 + I_1\overline{S}_1S_0 + I_2S_1\overline{S}_0 + I_3S_1S_0$$

$$I_0 = 0,\ I_1 = I_2 = I_3 = 1$$

So,

$$f = 0 + \overline{x}y + x\overline{y} + xy = \overline{x}y + x\overline{y} + xy$$

$$= \overline{x}y + x(y + \overline{y}) = \overline{x}y + x \qquad \mathbf{a}\ y + \overline{y} = 1$$

$$= (\overline{x} + x)(x + y) \qquad A + BC = (A + B)(A + C)$$

$$= x + y \qquad \because\ \overline{x} + x = 1$$

SOL 1.8.128 Option (C) is correct.

Since gain-bandwidth product remains constant

Therefore $10^5 \,\#\, 10 = 100 \,\#\, f_{CL}$

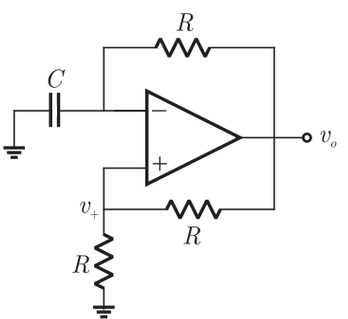
$$f_{CL} = 10 \text{ kHz}$$

SOL 1.8.129 Option (B) is correct.

Given circuit is an astable multi vibrator circuit, time period is given as

$$T = 2\tau \ln\left(\frac{1+\beta}{1-\beta}\right),\quad \tau = RC$$

$\beta \rightarrow$ feedback factor



$$\beta = \frac{v_+}{v_o} = \frac{1}{2}$$

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So, $$T = 2\tau \ln\left(\frac{1+\frac{1}{2}}{1-\frac{1}{2}}\right) = 2\tau \ln 3$$

SOL 1.8.130 Option (C) is correct.

MVI A, 10 H ⇒ MOV $(10)_H$ in accumulator

A =(10)H

MVI B, 10 H ⇒ MOV $(10)_H$ in register B

B = $(10)_H$

BACK : NOP

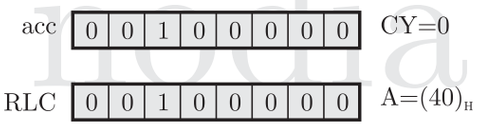
ADDB ⇒ Adds contents of register B to accumulator and result stores in accumulator

$$A = A + B = (10)_H + (10)_H$$

$$\begin{array}{r} 0\,0\,0\;\;1\,0\,0\,0\,0 \\ \underline{\text{ADD}\;\;0\,0\,0\;\;1\,0\,0\,0\,0} \\ A = 0\,0\,1\;\;0\,0\,0\,0\,0 \end{array}$$

$$= (20)_H$$

RLC ⇒ Rotate accumulator left without carry



JNC BACK ⇒ JUMP TO Back if $CY = 0$

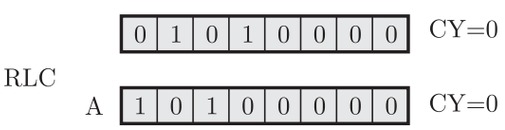
NOP

ADD B ⇒A = $A + B$

$$= (40)_H + (10)_H$$

$$\begin{array}{r} 0\,1\,0\,0\;\;0\,0\,0\,0 \\ \underline{\text{ADD}\;\;0\,0\,0\,1\;\;0\,0\,0\,0} \\ A = 0\,1\,0\,1\;\;0\,0\,0\,0 \end{array}$$

$$= (60)_H$$



$$A = (A0)_H$$

JNC BACK

NOP

ADDB ⇒ A = A + B

$$= (A0)_H + (10)_H$$

$$\begin{array}{r} 1\,0\,1\,0\;\;0\,0\,0\,0 \\ \underline{\text{ADD}\;\;0\,0\,0\,1\;\;0\,0\,0\,0} \\ A = 1\,0\,1\,1\;\;0\,0\,0\,0 \end{array}$$

$$A = (B0)_H$$

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	1	0	1	1	0	0	0	0

CY=0

RLC

A

	0	1	1	0	0	0	0	0

CY=1

CY = 1 So it goes to HLT.

therefore NOP will be executed 3 times.

SOL 1.8.131 Option (D) is correct.

Leakage current is given by

$$I_{\text{Leakage}} = \frac{Q'}{t} = \frac{0.5 \times \frac{1}{100} \times Q}{t} = \frac{0.5 \times \frac{1}{100} \times CV}{t}$$

$$= \frac{0.5 \times 10^{-2} \times 0.1 \times 10^{-9} \times 5}{1 \times 10^{-6}}$$

$$= \frac{25 \times 10^{-13}}{10^{-6}} = 2.5 \times 10^{-6} = 2.5\,\mu\text{A}$$

SOL 1.8.132 Option (A) is correct.

Slew rate is defined as the maximum rate of change in output voltage per unit time.

$$\text{Slew rate} = \frac{dv_0}{dt}$$

For voltage follower, $v_0 = v_{in}$

So, $\text{Slew rate} = \frac{dv_{in}}{dt}$, $v_{in} = 10\sin\omega t$

$$= \frac{d}{dt}(10\sin\omega t) = 10\omega\cos\omega t$$

$$= 10\omega = 62.8 \text{ volt}/\mu\text{sec (given)}$$

$$10 \# 2\pi f = 62.8 \# 10^6$$

$$f = \frac{62.8 \# 10^6}{62.8} = 1 \text{ MHz}$$

SOL 1.8.133 Option (C) is correct.

Trans conductance of an n-channel JFET, is given by.

$$g_m = \frac{2I_{DS}}{2V_{GS}} = \frac{-2I_{DSS}}{V_P}\left(1 - \frac{V_{GS}}{V_P}\right)$$

Trans conductance (g_m) is maximum when gate - to - source voltage

$$V_{GS} = 0$$

$$(g_m)_{\max} = \frac{-2I_{DSS}}{V_P}$$

So, $g_m = (g_m)_{\max}\left(1 - \frac{V_{GS}}{V_P}\right)$

Here $1 = (g_m)_{\max}\left(1 - \frac{(-3)}{(-5)}\right) = (g_m)_{\max} \# \frac{2}{5}$

$$(g_m)_{\max} = \frac{5}{2} = 2.5$$

SOL 1.8.134 Option () is correct.

The circuit is a synchronous counter.

Where input to the flip flops are

$$D_3 = \overline{Q_3 + Q_2 + Q_1}$$

$$D_2 = Q_3,\ D_1 = Q_2,\ D_0 = Q_1$$

Truth table of the circuit can be drawn as

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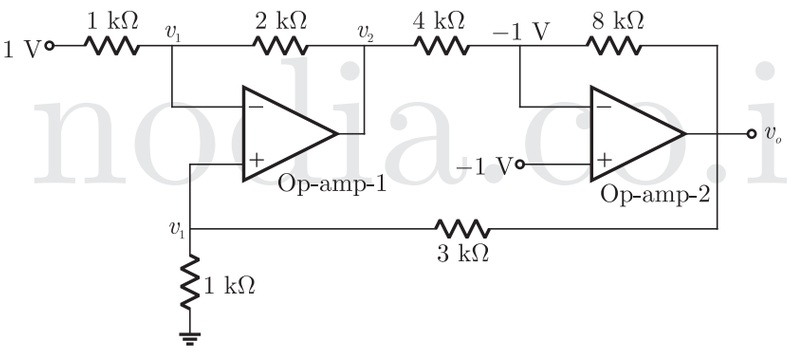
CLK	Q_3	Q_2	Q_1	Q_0
Initial state	1	1	1	0
1	0	1	1	1
2	0	0	1	1
3	0	0	0	1
4	1	0	0	0
5	0	1	0	0
6	0	0	1	0
7	0	0	0	1
8	1	0	0	0

From the truth table we can see that counter states at $N = 4$ and $N = 8$ are same. So mod number is 4.

SOL 1.8.135 Option (B) is correct.

In the circuit



Writing node equation in the circuit at the negative terminal of op amp-1

$$\frac{v_1 - 1}{1} + \frac{v_1 - v_2}{2} = 0$$

$$3v_1 - v_2 = 2 \quad \ldots(1)$$

Similarly, at the positive terminal of op amp-1

$$\frac{v_1 - v_o}{3} + \frac{v_1 - 0}{1} = 0$$

$$4v_1 - v_o = 0 \quad \ldots(2)$$

At the negative terminals of op-amp-2

$$\left(\frac{-1 - v_2}{4}\right) + \left(\frac{-1 - v_o}{8}\right) = 0$$

$$-2 - 2v_2 - 1 - v_o = 0$$

$$v_o + 2v_2 = -3 \quad \ldots(3)$$

From equation (1) and (2)

$$3\frac{v_o}{4} - 2v_2 = 1$$

From equation (3)

$$\frac{3}{4}v_o - 2(-3 - v_o) = 1$$

$$\frac{3}{4}v_o + v_o = -5$$

$$\frac{7}{4}v_o = -5$$

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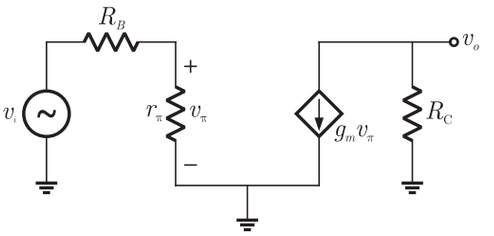
$$v_o = -\frac{20}{7} \text{ volt}$$

SOL 1.8.136 Option (C) is correct.

Small signal circuit is (mid-band frequency range)



$$C_E \to 0, \text{ for mid-band frequencies}$$

$$v_o = -g_m v_\pi R_C$$

In the input loop

$$v_\pi = \frac{v_i r_\pi}{R_B + r_\pi}$$

So, $$v_o = \frac{-g_m R_C r_\pi v_i}{R_B + r_\pi}$$

Gain $$A_v = \frac{v_o}{v_i} = \frac{-g_m r_\pi R_C}{R_B + r_\pi}$$

Trans-conductance

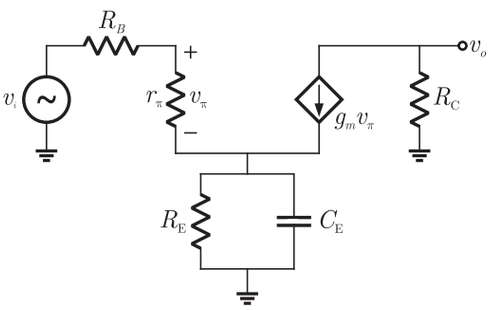
$$g_m = \frac{I_C}{V_T} = \frac{(1 \text{ mA})}{(26 \text{ mV})} = \frac{1}{26} \text{ A/V}$$

$$g_m r_\pi = \beta_0 \Rightarrow r_\pi = \frac{\beta_0}{g_m} = 200 \,\#\, 26 = 5.2 \text{ k}\Omega$$

So gain $$A_v = \frac{-200 \,\#\, (1 \text{ k}\Omega)}{(25 \text{ k}\Omega + 5.2 \text{ k}\Omega)} = -6.62$$

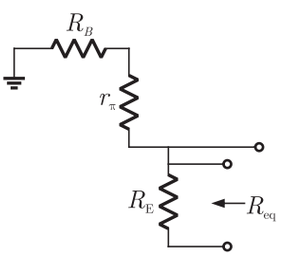
SOL 1.8.137 Option (B) is correct.

Cut off frequency due to C_E is obtained as



$$f_0 = \frac{1}{2\pi R_{eq} C_E}$$

Req " Equivalent resistance seen through capacitor C_E



$$\text{Req} = R_E \lessdot R_B + r_\pi = \frac{R_E (R_B + r_\pi)}{R_E + R_B + r_\pi}$$

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So $$f_0 = \frac{1(R_E + R_B + r_\pi)}{2\pi R_E (R_B + r_\pi) C_E} = 10 \text{ Hz (given)}$$

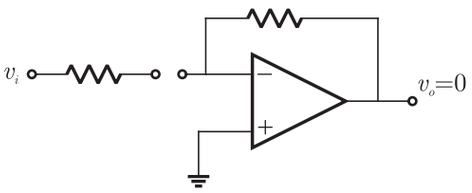
So, $$C_E = \frac{(0.1 + 25 + 5.2) \# 10^3}{2\pi \# 0.1 (25 + 5.2) \# 10^6} = 1.59 \text{ mF}$$

SOL 1.8.138 Option (D) is correct.

We can approximately analyze the circuit at low and high frequencies as following.

For low frequencies ω " 0 & $\frac{1}{\omega_c}$ " 3 (i.e. capacitor is open)

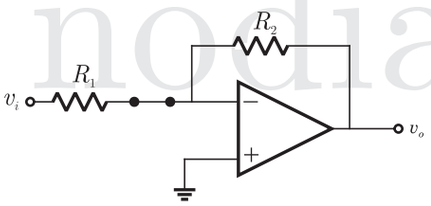
Equivalent circuit is



So, it does not pass the low frequencies.

For high frequencies ω " 3 & $\frac{1}{\omega_c}$ " 0 (i.e. capacitor is short)

Equivalent circuit is



$$v_o = -\frac{R_2}{R_1} v_i$$

So it does pass the high frequencies. This is a high pass filter.

SOL 1.8.139 At high frequency ω " 3 & $\frac{1}{\omega_c}$ " 0, capacitor behaves as short circuit and gain of the filter is given as

$$|A_v| = \left| -\frac{R_2}{R_1} \right| = 10$$

$$R_2 = 10\ R_1$$

Input resistance of the circuit $R_{in} = R_1 = 100 \text{ k}\Omega$

So, $R_2 = 10 \# 100 \text{ k}\Omega = 1 \text{ M}\Omega$

Transfer function of the circuit

$$\frac{V_o(j\omega)}{V_i(j\omega)} = \frac{-j\omega R_2 C}{1 + j\omega R_1 C}$$

High frequency gain $|A_{v\infty}| = 10$

At cutoff frequency gain is

$$|A_v| = \frac{10}{\sqrt{2}} = \left| \frac{-j\omega_c R_2 C}{1 + j\omega_c R_1 C} \right|$$

$$\frac{10}{\sqrt{2}} = \frac{\omega_c R_2 C}{\sqrt{1 + \omega_c^2 R_1^2 C^2}}$$

$$100 + 100\omega_c^2 R_1^2 C^2 = 2\omega_c^2 R_2^2 C^2$$

$$100 + 100 \times \omega_c^2 \times 10^{10} \times C^2 = 2 \times \omega_c^2 \times 10^{12} \times C^2$$

$$100 = \omega_c^2 C^2 \times 10^{12}$$

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$$C^2 = \frac{100}{\omega_c^2 \times 10^{12}}$$

$$C = \frac{1}{2\pi f_c \times 10^4}$$

$$= \frac{1}{2 \# 3.14 \# 10^3 \# 10^4}$$

$$= 15.92 \text{ nF}$$

****

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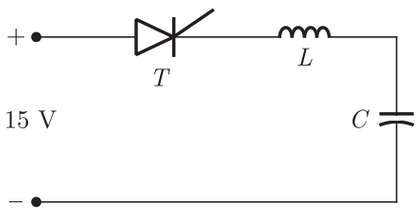
9

POWER ELECTRONICS

YEAR 2013 TWO MARKS

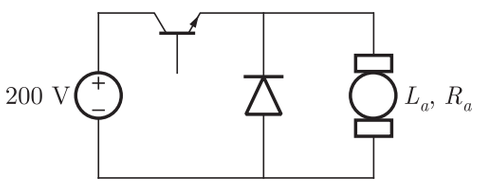
MCQ 1.9.1 Thyristor T in the figure below is initially off and is triggered with a single pulse of width $10\,\mu s$. It is given that $L = \left(\frac{100}{\pi}\right)\mu H$ and $C = \left(\frac{100}{\pi}\right)\mu F$. Assuming latching and holding currents of the thyristor are both zero and the initial charge on C is zero, T conducts for



(A) $10\,\mu s$ (B) $50\,\mu s$

(C) $100\,\mu s$ (D) $200\,\mu s$

MCQ 1.9.2 The separately excited dc motor in the figure below has a rated armature current of $20\,A$ and a rated armature voltage of $150\,V$. An ideal chopper switching at $5\,kHz$ is used to control the armature voltage. If $L_a = 0.1\,mH$, $R_a = 1\,\Omega$, neglecting armature reaction, the duty ratio of the chopper to obtain 50% of the rated torque at the rated speed and the rated field current is

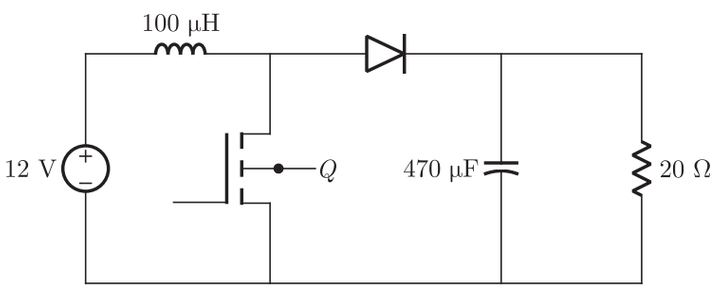


(A) 0.4 (B) 0.5

(C) 0.6 (D) 0.7

Common Data Questions: 3 & 4

In the figure shown below, the chopper feeds a resistive load from a battery source. MOSFET Q is switched at $250\,kHz$, with duty ratio of 0.4. All elements of the circuit are assumed to be ideal



MCQ 1.9.3 The Peak to Peak source current ripple in amps is

(A) 0.96 (B) 0.144

(C) 0.192 (D) 0.228

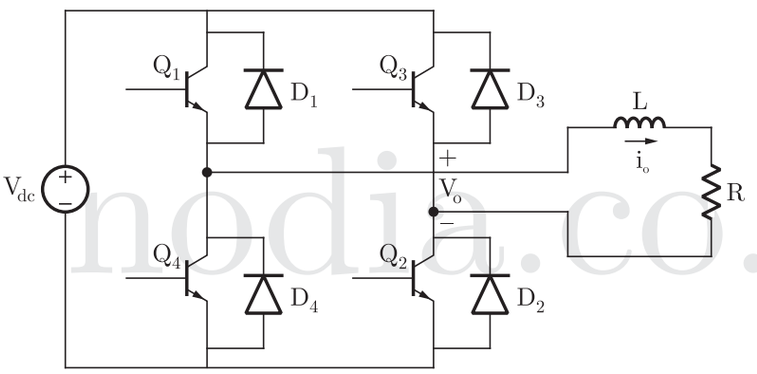
MCQ 1.9.4 The average source current in Amps in steady-state is

(A) 3/2 (B) 5/3

(C) 5/2 (D) 15/4

Statement for Linked Answer Questions: 5 & 6

The Voltage Source Inverter (VSI) shown in the figure below is switched to provide a 50 Hz, square wave ac output voltage V_o across an RL load. Reference polarity of V_o and reference direction of the output current i_o are indicated in the figure. It is given that $R = 3$ ohms, $L = 9.55$ mH.



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MCQ 1.9.5 In the interval when $V_0 < 0$ and $i_0 > 0$ the pair of devices which conducts the load current is

(A) Q_1, Q_2 (B) Q_3, Q_4

(C) D_1, D_2 (D) D_3, D_4

MCQ 1.9.6 Appropriate transition i.e., Zero Voltage Switching (ZVS)/Zero Current Switching (ZCS) of the IGBTs during turn-on/turn-off is

(A) ZVS during turn off (B) ZVS during turn-on

(C) ZCS during turn off (D) ZCS during turn-on

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MCQ 1.9.7 A half-controlled single-phase bridge rectifier is supplying an R-L load. It is operated at a firing angle α and the load current is continuous. The fraction of cycle that the freewheeling diode conducts is

(A) 1/2 (B) $(1 - \alpha/\pi)$

(C) $\alpha/2\pi$ (D) α/π

MCQ 1.9.8 The typical ratio of latching current to holding current in a 20 A thyristor is

(A) 5.0 (B) 2.0

(C) 1.0 (D) 0.5

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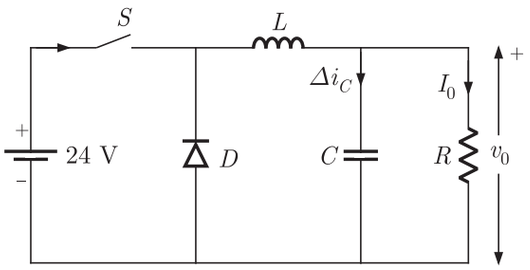
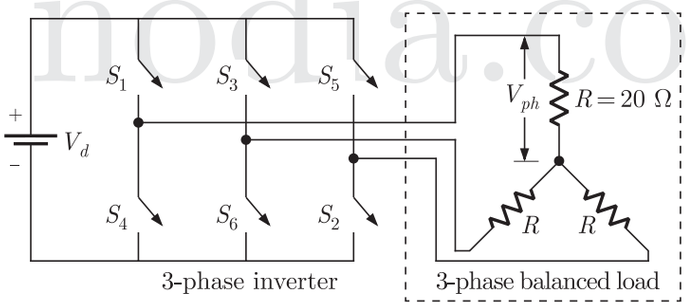
MCQ 1.9.9 In the circuit shown, an ideal switch S is operated at 100 kHz with a duty ratio of 50%. Given that Δi_c is 1.6 A peak-to-peak and I_0 is 5 A dc, the peak current in S, is



(A) 6.6 A (B) 5.0 A
(C) 5.8 A (D) 4.2 A

Common Data for Questions 10 and 11

In the 3-phase inverter circuit shown, the load is balanced and the gating scheme is 180° conduction mode. All the switching devices are ideal.

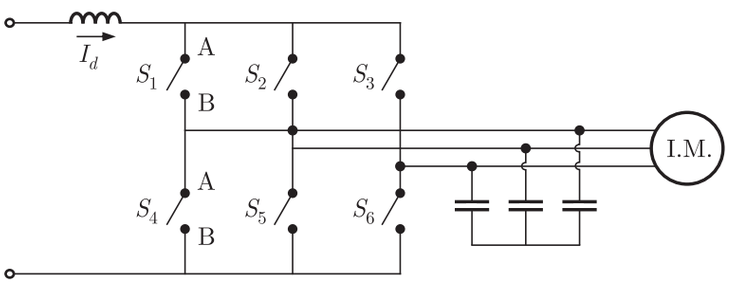


MCQ 1.9.10 The rms value of load phase voltage is
(A) 106.1 V (B) 141.4 V
(C) 212.2 V (D) 282.8 V

MCQ 1.9.11 If the dc bus voltage $V_d = 300$ V, the power consumed by 3-phase load is
(A) 1.5 kW (B) 2.0 kW
(C) 2.5 kW (D) 3.0 kW

YEAR 2011 ONE MARK

MCQ 1.9.12 A three phase current source inverter used for the speed control of an induction motor is to be realized using MOSFET switches as shown below. Switches S_1 to S_6 are identical switches.



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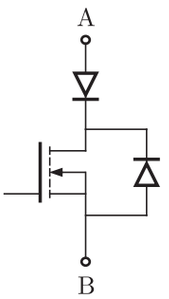
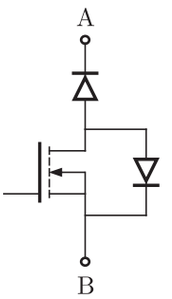
The proper configuration for realizing switches S_1 to S_6 is

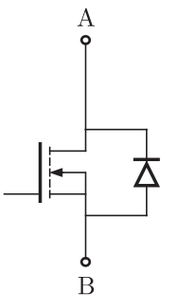
(A)



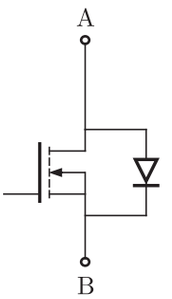
(B)



(C)



(D)



MCQ 1.9.13 Circuit turn-off time of an SCR is defined as the time

(A) taken by the SCR turn to be off

(B) required for the SCR current to become zero

(C) for which the SCR is reverse biased by the commutation circuit

(D) for which the SCR is reverse biased to reduce its current below the holding current

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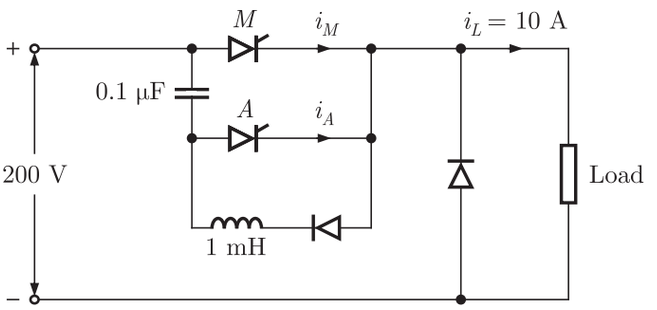
YEAR 2011 TWO MARKS

MCQ 1.9.14 A voltage commutated chopper circuit, operated at 500 Hz, is shown below.



If the maximum value of load current is 10 A, then the maximum current through the main (M) and auxiliary (A) thyristors will be

(A) $i_{M\max} = 12$ A and $i_{A\max} = 10$ A

(B) $i_{M\max} = 12$ A and $i_{A\max} = 2$ A

(C) $i_{M\max} = 10$ A and $i_{A\max} = 12$ A

(D) $i_{M\max} = 10$ A and $i_{A\max} = 8$ A

Statement for Linked Answer Questions: 9 & 10

A solar energy installation utilize a three – phase bridge converter to feed energy

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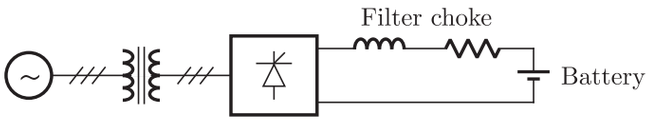
into power system through a transformer of 400 V/400 V, as shown below.



The energy is collected in a bank of 400 V battery and is connected to converter through a large filter choke of resistance $10\,\Omega$.

MCQ 1.9.15 The maximum current through the battery will be

(A) 14 A (B) 40 A

(C) 80 A (D) 94 A

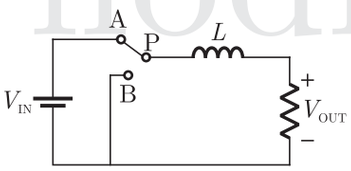
MCQ 1.9.16 The kVA rating of the input transformer is

(A) 53.2 kVA (B) 46.0 kVA

(C) 22.6 kVA (D) 7.5 kVA

YEAR 2010 ONE MARK

MCQ 1.9.17 The power electronic converter shown in the figure has a single-pole double-throw switch. The pole P of the switch is connected alternately to throws A and B. The converter shown is a



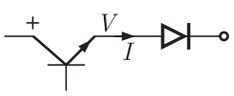
(A) step down chopper (buck converter)

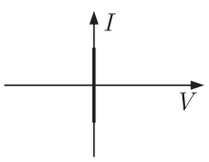
(B) half-wave rectifier

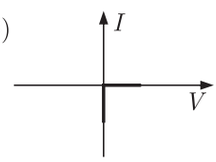
(C) step-up chopper (boost converter)

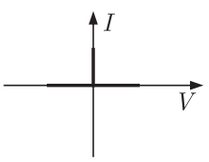
(D) full-wave rectifier

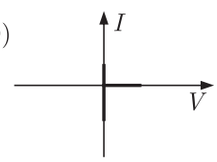
MCQ 1.9.18 Figure shows a composite switch consisting of a power transistor (BJT) in series with a diode. Assuming that the transistor switch and the diode are ideal, the I-V characteristic of the composite switch is



(A) 

(B) 

(C) 

(D) 

MCQ 1.9.19 The fully controlled thyristor converter in the figure is fed from a single-phase

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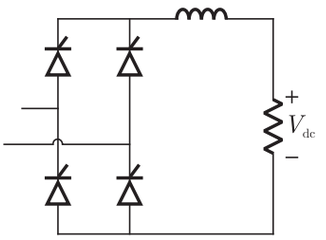
source. When the firing angle is 0°, the dc output voltage of the converter is 300 V. What will be the output voltage for a firing angle of 60°, assuming continuous conduction



(A) 150 V
(B) 210 V
(C) 300 V
(D) 100π V

YEAR 2009 ONE MARK

MCQ 1.9.20 An SCR is considered to be a semi-controlled device because
(A) It can be turned OFF but not ON with a gate pulse.
(B) It conducts only during one half-cycle of an alternating current wave.
(C) It can be turned ON but not OFF with a gate pulse.
(D) It can be turned ON only during one half-cycle of an alternating voltage wave.

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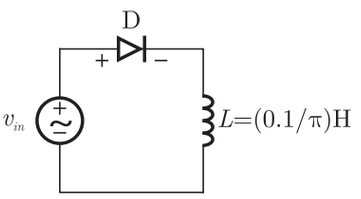
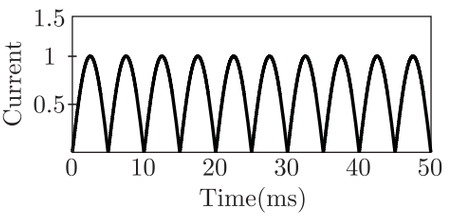
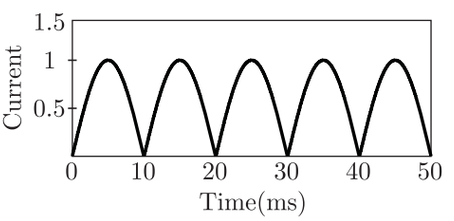
MCQ 1.9.21 The circuit shows an ideal diode connected to a pure inductor and is connected to a purely sinusoidal 50 Hz voltage source. Under ideal conditions the current waveform through the inductor will look like.



(A)



(B)



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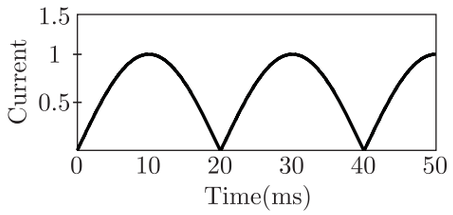
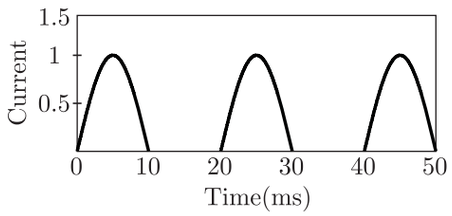
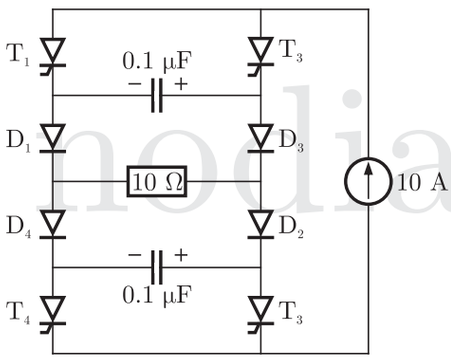
(C)



(D)



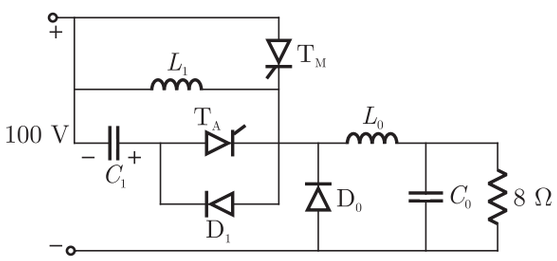
MCQ 1.9.22 The Current Source Inverter shown in figure is operated by alternately turning on thyristor pairs (T_1, T_2) and (T_3, T_4). If the load is purely resistive, the theoretical maximum output frequency obtainable will be



(A) 125 kHz (B) 250 kHz

(C) 500 kHz (D) 50 kHz

MCQ 1.9.23 In the chopper circuit shown, the main thyristor (T_M) is operated at a duty ratio of 0.8 which is much larger the commutation interval. If the maximum allowable reapplied dv/dt on T_M is 50 V/μs, what should be the theoretical minimum value of C_1 ? Assume current ripple through L_0 to be negligible.



(A) 0.2 μF (B) 0.02 μF

(C) 2 μF (D) 20 μF

MCQ 1.9.24 Match the switch arrangements on the top row to the steady-state V-I characteristics on the lower row. The steady state operating points are shown by large black dots.

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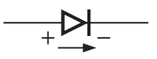
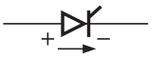
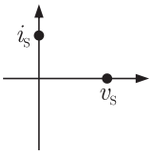
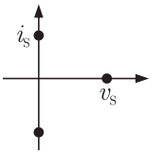

(P)

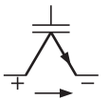

(Q)

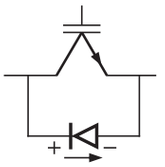


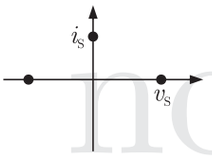
(i)



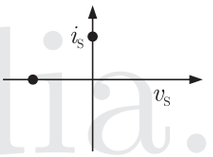
(ii)


(R)


(S)



(iii)



(iv)

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(A) P-I, Q-II, R-III, S-IV
(B) P-II, Q-IV, R-I, S-III
(C) P-IV, Q-III, R-I, S-II
(D) P-IV, Q-III, R-II, S-I

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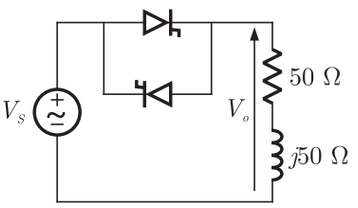
MCQ 1.9.25 In the single phase voltage controller circuit shown in the figure, for what range of triggering angle (α), the input voltage (V_0) is not controllable ?



(A) $0^\circ < \alpha < 45^\circ$
(B) $45^\circ < \alpha < 135^\circ$
(C) $90^\circ < \alpha < 180^\circ$
(D) $135^\circ < \alpha < 180^\circ$

MCQ 1.9.26 A 3-phase voltage source inverter is operated in 180° conduction mode. Which one of the following statements is true ?

(A) Both pole-voltage and line-voltage will have 3rd harmonic components
(B) Pole-voltage will have 3rd harmonic component but line-voltage will be free from 3rd harmonic
(C) Line-voltage will have 3rd harmonic component but pole-voltage will be free from 3rd harmonic
(D) Both pole-voltage and line-voltage will be free from 3rd harmonic components

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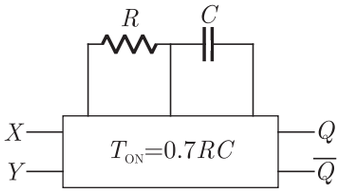
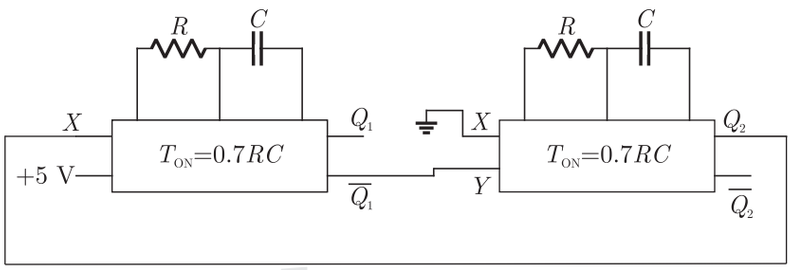
MCQ 1.9.27 The truth table of monoshot shown in the figure is given in the table below :

X	Y	Q	$\overline{Q}$
0	↑	⊓	⊔
↓	1	⊓	⊔



Two monoshots, one positive edge triggered and other negative edge triggered, are connected shown in the figure, The pulse widths of the two monoshot outputs Q_1 and Q_2 are T_{ON_1} and T_{ON_2} respectively.



The frequency and the duty cycle of the signal at Q_1 will respectively be

(A) $f = \dfrac{1}{T_{ON_1} + T_{ON_2}}$, $D = \dfrac{1}{5}$ (B) $f = \dfrac{1}{T_{ON_1} + T_{ON_2}}$, $D = \dfrac{T_{ON_2}}{T_{ON_1} + T_{ON_2}}$

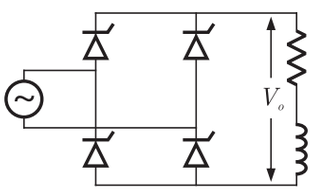
(C) $f = \dfrac{1}{T_{ON_1}}$, $D = \dfrac{T_{ON_1}}{T_{ON_1} + T_{ON_2}}$ (D) $f = \dfrac{1}{T_{ON_2}}$, $D = \dfrac{T_{ON_1}}{T_{ON_1} + T_{ON_2}}$

MCQ 1.9.28 A single phase fully controlled bridge converter supplies a load drawing constant and ripple free load current, if the triggering angle is 30c, the input power factor will be

(A) 0.65 (B) 0.78

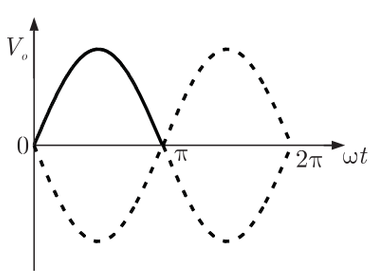
(C) 0.85 (D) 0.866

MCQ 1.9.29 A single-phase half controlled converter shown in the figure feeding power to highly inductive load. The converter is operating at a firing angle of 60c.

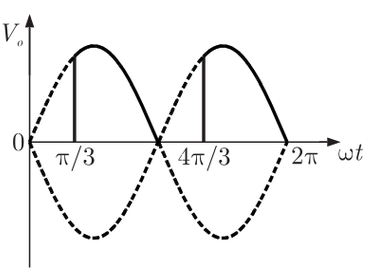


If the firing pulses are suddenly removed, the steady state voltage (V_0) waveform of the converter will become

(A)



(B)



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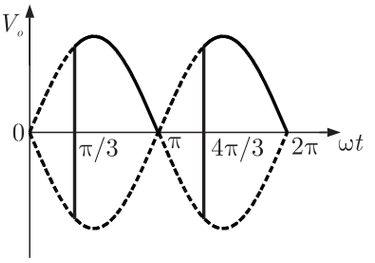
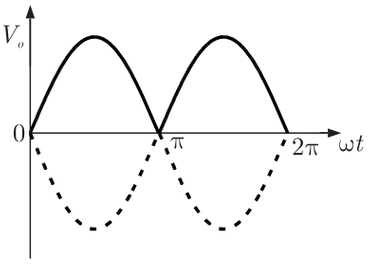
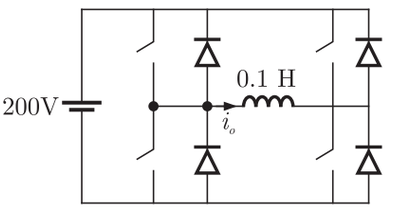
(C)



(D)



MCQ 1.9.30 A single phase source inverter is feeding a purely inductive load as shown in the figure. The inverter is operated at 50 Hz in 180c square wave mode. Assume that the load current does not have any dc component. The peak value of the inductor current i_0 will be



(A) 6.37 A
(B) 10 A
(C) 20 A
(D) 40 A

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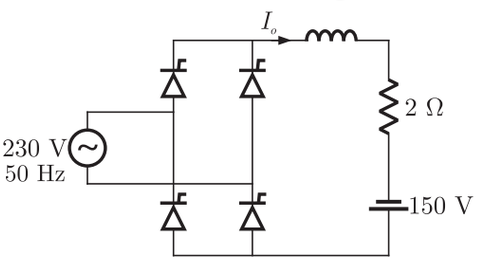
MCQ 1.9.31 A single phase fully controlled converter bridge is used for electrical braking of a separately excited dc motor. The dc motor load is represented by an equivalent circuit as shown in the figure.



Assume that the load inductance is sufficient to ensure continuous and ripple free load current. The firing angle of the bridge for a load current of $I_0 = 10$ A will be

(A) 44c
(B) 51c
(C) 129c
(D) 136c

MCQ 1.9.32 A three phase fully controlled bridge converter is feeding a load drawing a constant and ripple free load current of 10 A at a firing angle of 30c. The approximate Total harmonic Distortion (%THD) and the rms value of fundamental component of input current will respectively be

(A) 31% and 6.8 A
(B) 31% and 7.8 A
(C) 66% and 6.8 A
(D) 66% and 7.8 A

MCQ 1.9.33 In the circuit shown in the figure, the switch is operated at a duty cycle of 0.5. A large capacitor is connected across the load. The inductor current is assumed to be continuous.

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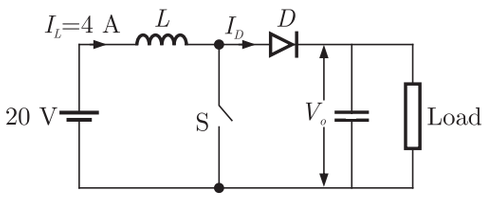

The average voltage across the load and the average current through the diode will respectively be

(A) 10 V, 2 A (B) 10 V, 8 A

(C) 40 V 2 A (D) 40 V, 8 A

YEAR 2007 ONE MARK

MCQ 1.9.34 A single-phase fully controlled thyristor bridge ac-dc converter is operating at a firing angle of 25c and an overlap angle of 10c with constant dc output current of 20 A. The fundamental power factor (displacement factor) at input ac mains is

(A) 0.78 (B) 0.827

(C) 0.866 (D) 0.9

MCQ 1.9.35 A three-phase, fully controlled thyristor bridge converter is used as line commutated inverter to feed 50 kW power 420 V dc to a three-phase, 415 V(line), 50 Hz ac mains. Consider dc link current to be constant. The rms current of the thyristor is

(A) 119.05 A (B) 79.37 A

(C) 68.73 A (D) 39.68 A

MCQ 1.9.36 A single phase full-wave half-controlled bridge converter feeds an inductive load. The two SCRs in the converter are connected to a common DC bus. The converter has to have a freewheeling diode.

(A) because the converter inherently does not provide for free-wheeling

(B) because the converter does not provide for free-wheeling for high values of triggering angles

(C) or else the free-wheeling action of the converter will cause shorting of the AC supply

(D) or else if a gate pulse to one of the SCRs is missed, it will subsequently cause a high load current in the other SCR.

MCQ 1.9.37 "Six MOSFETs connected in a bridge configuration (having no other power device) must be operated as a Voltage Source Inverter (VSI)". This statement is

(A) True, because being majority carrier devices MOSFETs are voltage driven.

(B) True, because MOSFETs hav inherently anti-parallel diodes

(C) False, because it can be operated both as Current Source Inverter (CSI) or a VSI

(D) False, because MOSFETs can be operated as excellent constant current sources in the saturation region.

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MCQ 1.9.38 A single-phase voltages source inverter is controlled in a single pulse-width modulated mode with a pulse width of 150c in each half cycle. Total

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harmonic distortion is defined as

$$\text{THD} = \frac{\sqrt{V_{rms}^2 - V_1^2}}{V_1} \times 100$$

where V_1 is the rms value of the fundamental component of the output voltage. The THD of output ac voltage waveform is

(A) 65.65% (B) 48.42%

(C) 31.83% (D) 30.49%

MCQ 1.9.39 A three-phase, 440 V, 50 Hz ac mains fed thyristor bridge is feeding a 440 V dc, 15 kW, 1500 rpm separately excited dc motor with a ripple free continuos current in the dc link under all operating conditions, Neglecting the losses, the power factor of the ac mains at half the rated speed is

(A) 0.354 (B) 0.372

(C) 0.90 (D) 0.955

MCQ 1.9.40 A single-phase, 230 V, 50 Hz ac mains fed step down transformer (4:1) is supplying power to a half-wave uncontrolled ac-dc converter used for charging a battery (12 V dc) with the series current limiting resistor being 19.04 Ω. The charging current is

(A) 2.43 A (B) 1.65 A

(C) 1.22 A (D) 1.0 A

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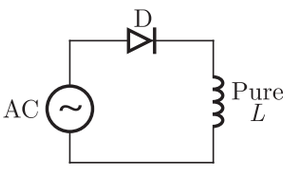
MCQ 1.9.41 In the circuit of adjacent figure the diode connects the ac source to a pure inductance L.

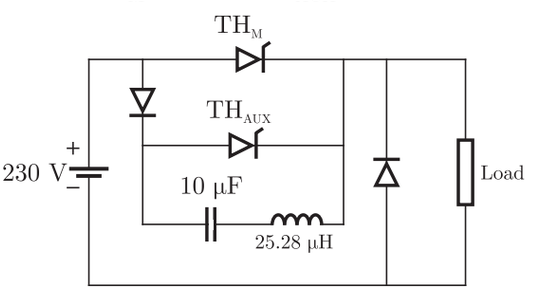


The diode conducts for

(A) 90c (B) 180c

(C) 270c (D) 360c

MCQ 1.9.42 The circuit in the figure is a current commutated dc-dc chopper where, Th_M is the main SCR and Th_AUX is the auxiliary SCR. The load current is constant at 10 A. Th_M is ON. Th_AUX is trigged at $t = 0$. Th_M is turned OFF between.



(A) $0\ \mu s < t \# 25\ \mu s$ (B) $25\ \mu s < t \# 50\ \mu s$

(C) $50\ \mu s < t \# 75\ \mu s$ (D) $75\ \mu s < t \# 100\ \mu s$

Common Data for Question 37 and 38.

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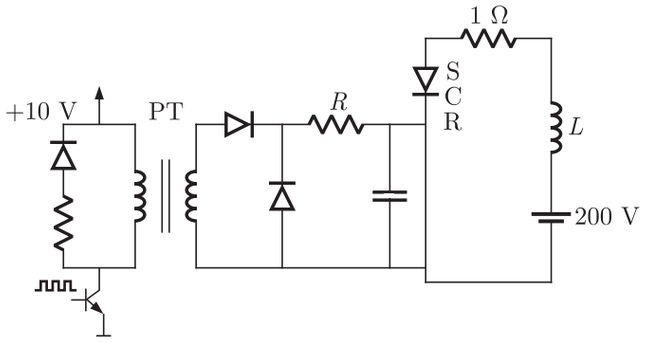
A 1:1 Pulse Transformer (PT) is used to trigger the SCR in the adjacent figure. The SCR is rated at 1.5 kV, 250 A with $I_L = 250$ mA, $I_H = 150$ mA, and $I_{G\max} = 150$ mA, $I_{G\min} = 100$ mA. The SCR is connected to an inductive load, where $L = 150$ mH in series with a small resistance and the supply voltage is 200 V dc. The forward drops of all transistors/diodes and gate-cathode junction during ON state are 1.0 V



MCQ 1.9.43 The resistance R should be

(A) 4.7 kΩ (B) 470 kΩ

(C) 47 Ω (D) 4.7 Ω

MCQ 1.9.44 The minimum approximate volt-second rating of pulse transformer suitable for triggering the SCR should be : (volt-second rating is the maximum of product of the voltage and the width of the pulse that may applied)

(A) 2000 μV-s (B) 200 μV-s

(C) 20 μV-s (D) 2 μV-s

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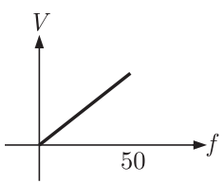
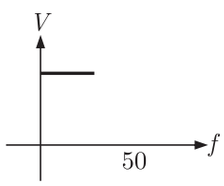
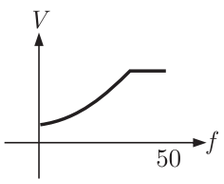
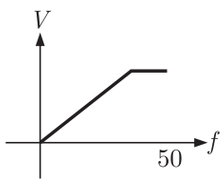
MCQ 1.9.45 The speed of a 3-phase, 440 V, 50 Hz induction motor is to be controlled over a wide range from zero speed to 1.5 time the rated speed using a 3-phase voltage source inverter. It is desired to keep the flux in the machine constant in the constant torque region by controlling the terminal voltage as the frequency changes. The inverter output voltage vs frequency characteristic should be

(A)


(B)


(C)


(D)


MCQ 1.9.46 A single-phase half wave uncontrolled converter circuit is shown in figure. A 2-winding transformer is used at the input for isolation. Assuming the load current to be constant and $V = V_m \sin \omega t$, the current waveform through diode D_2 will be

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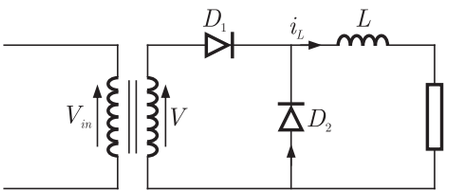
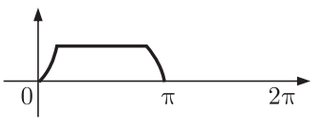
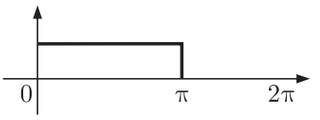


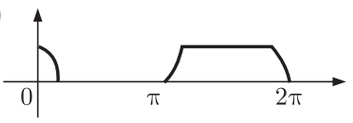
(A)



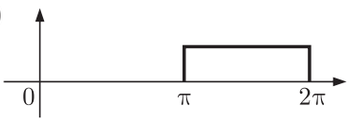
(B)



(C)



(D)



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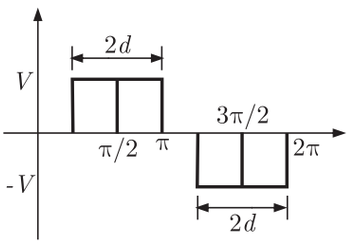
MCQ 1.9.47 A single-phase inverter is operated in PWM mode generating a single-pulse of width $2d$ in the centre of each half cycle as shown in figure. It is found that the output voltage is free from 5th harmonic for pulse width 144c. What will be percentage of 3rd harmonic present in the output voltage ($V_{o3}/V_{o1\max}$) ?



(A) 0.0% (B) 19.6%

(C) 31.7% (D) 53.9%

MCQ 1.9.48 A 3-phase fully controlled bridge converter with free wheeling diode is fed from 400 V, 50 Hz AC source and is operating at a firing angle of 60c. The load current is assumed constant at 10 A due to high load inductance. The input displacement factor (IDF) and the input power factor (IPF) of the converter will be

(A) IDF = 0.867; IPF = 0.828 (B) IDF = 0.867; IPF = 0.552

(C) IDF = 0.5; IPF = 0.478 (D) IDF = 0.5; IPF = 0.318

MCQ 1.9.49 A voltage commutation circuit is shown in figure. If the turn-off time of the SCR is 50 μsec and a safety margin of 2 is considered, then what will be the approximate minimum value of capacitor required for proper commutation ?

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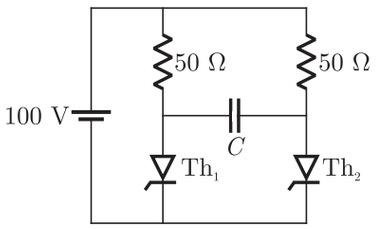
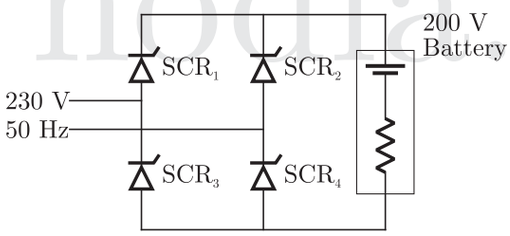


(A) 2.88 μF (B) 1.44 μF
(C) 0.91 μF (D) 0.72 μF

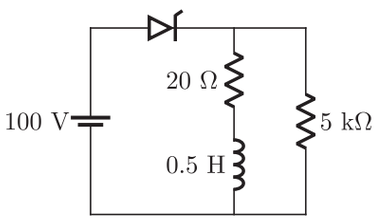
MCQ 1.9.50 A solar cell of 350 V is feeding power to an ac supply of 440 V, 50 Hz through a 3-phase fully controlled bridge converter. A large inductance is connected in the dc circuit to maintain the dc current at 20 A. If the solar cell resistance is 0.5 Ω ,then each thyristor will be reverse biased for a period of
(A) 125c (B) 120c
(C) 60c (D) 55c

MCQ 1.9.51 A single-phase bridge converter is used to charge a battery of 200 V having an internal resistance of 0.2 Ω as shown in figure. The SCRs are triggered by a constant dc signal. If SCR_2 gets open circuited, what will be the average charging current ?



(A) 23.8 A (B) 15 A
(C) 11.9 A (D) 3.54 A

MCQ 1.9.52 An SCR having a turn ON times of 5 μsec, latching current of 50 A and holding current of 40 mA is triggered by a short duration pulse and is used in the circuit shown in figure. The minimum pulse width required to turn the SCR ON will be



(A) 251 μsec (B) 150 μsec
(C) 100 μsec (D) 5 μsec

Data for Q. 53 and Q. 54 are given below. Solve the problems and choose the correct answers.

A voltage commutated chopper operating at 1 kHz is used to control the speed of dc as shown in figure. The load current is assumed to be constant at 10 A

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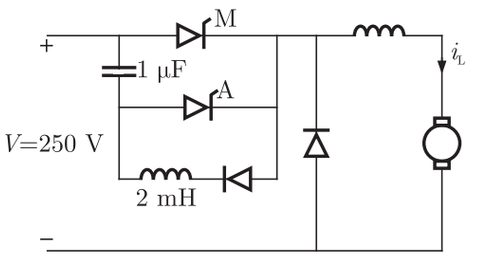

MCQ 1.9.53 The minimum time in μsec for which the SCR M should be ON is.

(A) 280 (B) 140

(C) 70 (D) 0

MCQ 1.9.54 The average output voltage of the chopper will be

(A) 70 V (B) 47.5 V

(C) 35 V (D) 0 V

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MCQ 1.9.55 The conduction loss versus device current characteristic of a power MOSFET is best approximated by

(A) a parabola

(B) a straight line

(C) a rectangular hyperbola

(D) an exponentially decaying function

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MCQ 1.9.56 A three-phase diode bridge rectifier is fed from a 400 V RMS, 50 Hz, three-phase AC source. If the load is purely resistive, then peak instantaneous output voltage is equal to

(A) 400 V (B) $400\sqrt{2}$ V

(C) $400\sqrt{\frac{2}{3}}$ V (D) $\frac{400}{\sqrt{3}}$ V

MCQ 1.9.57 The output voltage waveform of a three-phase square-wave inverter contains

(A) only even harmonics (B) both odd and even harmonic

(C) only odd harmonics (D) only triple harmonics

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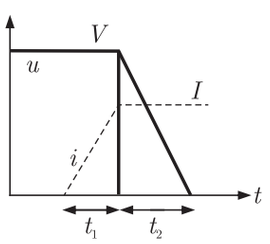
MCQ 1.9.58 The figure shows the voltage across a power semiconductor device and the current through the device during a switching transitions. If the transition a turn ON transition or a turn OFF transition ? What is the energy lost during the transition?



(A) Turn ON, $\frac{VI}{2}(t_1+t_2)$ (B) Turn OFF, $VI(t_1+t_2)$

(C) Turn ON, $VI(t_1+t_2)$ (D) Turn OFF, $\frac{VI}{2}(t_1+t_2)$

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MCQ 1.9.59 An electronics switch S is required to block voltage of either polarity during its OFF state as shown in the figure (a). This switch is required to conduct in only one direction its ON state as shown in the figure (b)

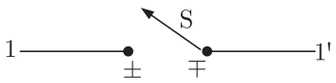
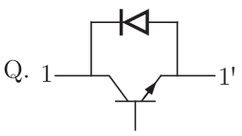
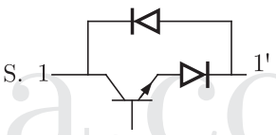


fig (a)

fig (b)

Which of the following are valid realizations of the switch S?





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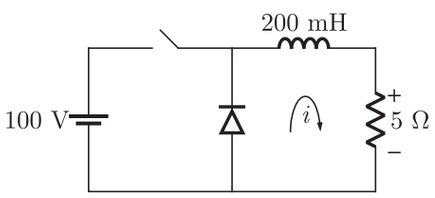
(A) Only P
(B) P and Q
(C) P and R
(D) R and S

MCQ 1.9.60 The given figure shows a step-down chopper switched at 1 kHz with a duty ratio $D = 0.5$. The peak-peak ripple in the load current is close to



(A) 10 A
(B) 0.5 A
(C) 0.125 A
(D) 0.25 A

MCQ 1.9.61 An electric motor, developing a starting torque of 15 Nm, starts with a load torque of 7 Nm on its shaft. If the acceleration at start is 2 rad/sec^2 , the moment of inertia of the system must be (neglecting viscous and coulomb friction)

(A) 0.25 kg-m^2
(B) 0.25 Nm^2
(C) 4 kg-m^2
(D) 4 Nm^2

MCQ 1.9.62 Consider a phase-controlled converter shown in the figure. The thyristor is fired at an angle α in every positive half cycle of the input voltage. If the peak value of the instantaneous output voltage equals 230 V, the firing angle α is close to

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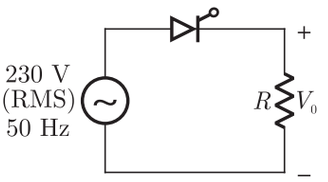

(A) 45c (B) 135c

(C) 90c (D) 83.6c

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MCQ 1.9.63 A bipolar junction transistor (BJT) is used as a power control switch by biasing it in the cut-off region (OFF state) or in the saturation region (ON state). In the ON state, for the BJT

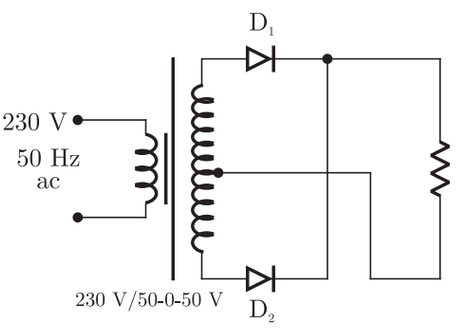
(A) both the base-emitter and base-collector junctions are reverse biased

(B) the base-emitter junction is reverse biased, and the base-collector junction is forward biased

(C) the base-emitter junction is forward biased, and the base-collector junction is reverse biased

(D) both the base-emitter and base-collector junctions are forward biased

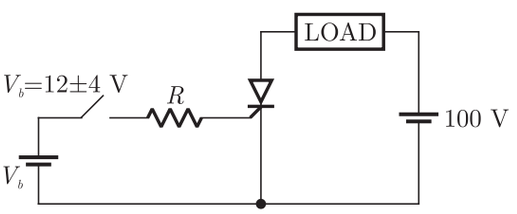
MCQ 1.9.64 The circuit in figure shows a full-wave rectifier. The input voltage is 230 V (rms) single-phase ac. The peak reverse voltage across the diodes D_1 and D_2 is



(A) $100\sqrt{2}$ V (B) 100 V

(C) $50\sqrt{2}$ V (D) 50 V

MCQ 1.9.65 The triggering circuit of a thyristor is shown in figure. The thyristor requires a gate current of 10 mA, for guaranteed turn-on. The value of R required for the thyristor to turn on reliably under all conditions of V_b variation is



(A) 10000 Ω (B) 1600 Ω

(C) 1200 Ω (D) 800 Ω

MCQ 1.9.66 The circuit in figure shows a 3-phase half-wave rectifier. The source is a symmetrical, 3-phase four-wire system. The line-to-line voltage of the source is

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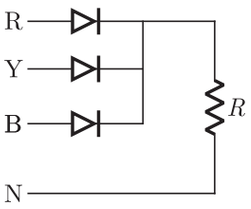
100 V. The supply frequency is 400 Hz. The ripple frequency at the output is



(A) 400 Hz
(B) 800 Hz
(C) 1200 Hz
(D) 2400 Hz

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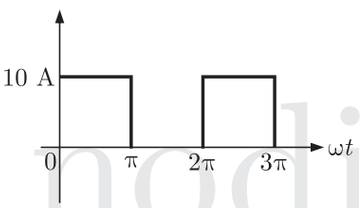
MCQ 1.9.67 A MOSFET rated for 15 A, carries a periodic current as shown in figure. The ON state resistance of the MOSFET is 0.15 Ω. The average ON state loss in the MOSFET is



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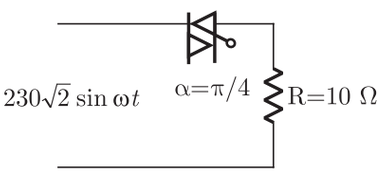
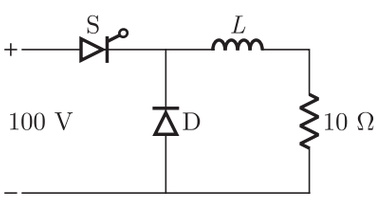
(A) 33.8 W
(B) 15.0 W
(C) 7.5 W
(D) 3.8 W

MCQ 1.9.68 The triac circuit shown in figure controls the ac output power to the resistive load. The peak power dissipation in the load is



(A) 3968 W
(B) 5290 W
(C) 7935 W
(D) 10580 W

MCQ 1.9.69 Figure shows a chopper operating from a 100 V dc input. The duty ratio of the main switch S is 0.8. The load is sufficiently inductive so that the load current is ripple free. The average current through the diode D under steady state is



(A) 1.6 A
(B) 6.4 A
(B) 8.0 A
(D) 10.0 A

MCQ 1.9.70 Figure shows a chopper. The device S_1 is the main switching device. S_2 is the auxiliary commutation device. S_1 is rated for 400 V, 60 A. S_2 is rated for 400 V,

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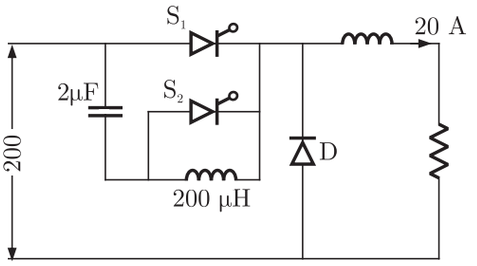
30 A. The load current is 20 A. The main device operates with a duty ratio of 0.5. The peak current through S_1 is



(A) 10 A (B) 20 A

(C) 30 A (D) 40 A

MCQ 1.9.71 A single-phase half-controlled rectifier is driving a separately excited dc motor. The dc motor has a back emf constant of 0.5 V/rpm. The armature current is 5 A without any ripple. The armature resistance is 2 Ω. The converter is working from a 230 V, single-phase ac source with a firing angle of 30c. Under this operating condition, the speed of the motor will be

(A) 339 rpm (B) 359 rpm

(C) 366 rpm (D) 386 rpm

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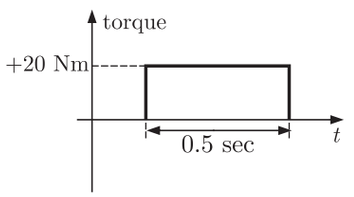
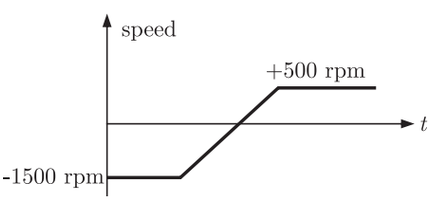
MCQ 1.9.72 A variable speed drive rated for 1500 rpm, 40 Nm is reversing under no load. Figure shows the reversing torque and the speed during the transient. The moment of inertia of the drive is





(A) 0.048 kg-m^2 (B) 0.064 km-m^2

(C) 0.096 kg-m^2 (D) 0.128 kg-m^2

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MCQ 1.9.73 Figure shows a thyristor with the standard terminations of anode (A), cathode (K), gate (G) and the different junctions named J1, J2 and J3. When the thyristor is turned on and conducting

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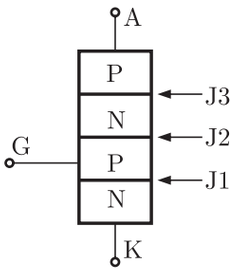


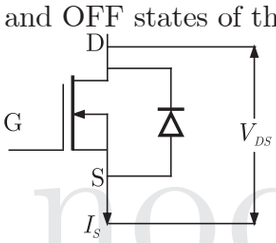
(A) J1 and J2 are forward biased and J3 is reverse biased

(B) J1 and J3 are forward biased and J2 is reverse biased

(C) J1 is forward biased and J2 and J3 are reverse biased

(D) J1, J2 and J3 are all forward biased

MCQ 1.9.74 Figure shows a MOSFET with an integral body diode. It is employed as a power switching device in the ON and OFF states through appropriate control. The ON and OFF states of the switch are given on the $V_{DS} - I_S$ plane by



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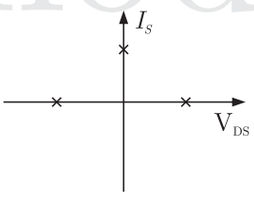
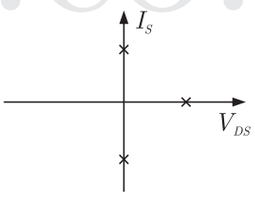
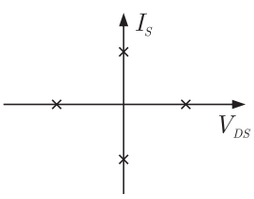
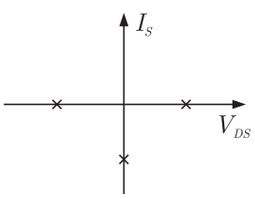
(A)


(B)


(C)


(D)


MCQ 1.9.75 The speed/torque regimes in a dc motor and the control methods suitable for the same are given respectively in List-II and List-I

List-I		List-II	
P.	Field Control	1.	Below base speed
Q.	Armature Control	2.	Above base speed
		3.	Above base torque
		4.	Below base torque

Codes:

(A) P-1, Q-3 (B) P-2, Q-1

(C) P-2, Q-3 (D) P-1, Q-4

MCQ 1.9.76 A fully controlled natural commutated 3-phase bridge rectifier is operating with a firing angle $\alpha = 30^{\circ}$, The peak to peak voltage ripple expressed as a ratio of the peak output dc voltage at the output of the converter bridge is

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(A) 0.5 (B) $\sqrt{3}/2$

(C) $\left(1-\frac{\sqrt{3}}{2}\right)$ (D) $\sqrt{3}-1$

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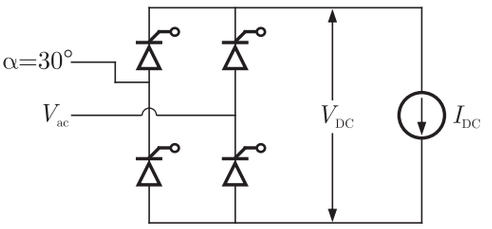
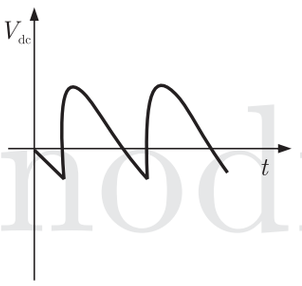
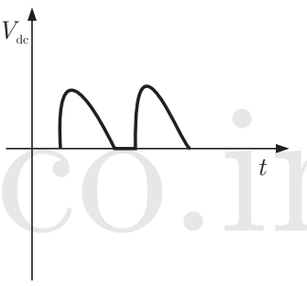
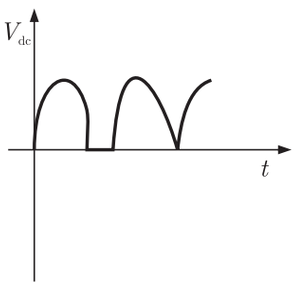
MCQ 1.9.77 A phase-controlled half-controlled single-phase converter is shown in figure. The control angle $\alpha = 30$

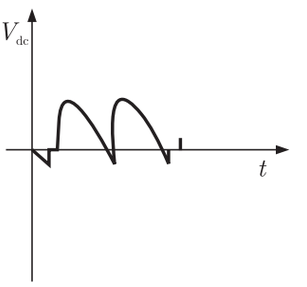


The output dc voltage wave shape will be as shown in

(A)


(B)


(C)


(D)


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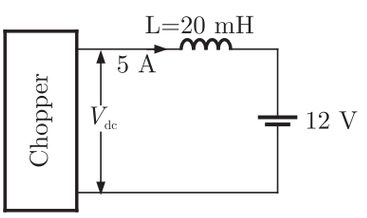
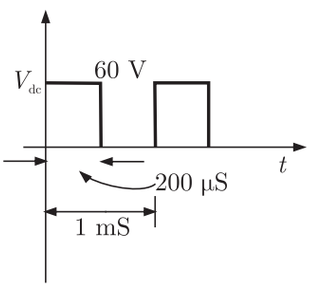
MCQ 1.9.78 A chopper is employed to charge a battery as shown in figure. The charging current is 5 A. The duty ratio is 0.2. The chopper output voltage is also shown in the figure. The peak to peak ripple current in the charging current is





(A) 0.48 A (B) 1.2 A

(C) 2.4 A (D) 1 A

MCQ 1.9.79 An inverter has a periodic output voltage with the output wave form as shown in figure

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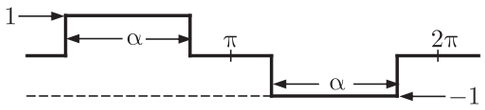

When the conduction angle $\alpha = 120$c, the rms fundamental component of the output voltage is

(A) 0.78 V (B) 1.10 V

(C) 0.90 V (D) 1.27 V

MCQ 1.9.80 With reference to the output wave form given in above figure , the output of the converter will be free from 5^{th} harmonic when

(A) $\alpha = 72$c (B) $\alpha = 36$c

(C) $\alpha = 150$c (D) $\alpha = 120$c

MCQ 1.9.81 An ac induction motor is used for a speed control application. It is driven from an inverter with a constant V/f control. The motor name-plate details are as follows (no. of poles = 2)

V: 415 V V_{Ph}: 3 V f: 50 Hz N: 2850 rpm

The motor runs with the inverter output frequency set at 40 Hz, and with half the rated slip. The running speed of the motor is

(A) 2400 rpm (B) 2280 rpm

(C) 2340 rpm (D) 2790 rpm

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MCQ 1.9.82 A six pulse thyristor rectifier bridge is connected to a balanced 50 Hz three phase ac source. Assuming that the dc output current of the rectifier is constant, the lowest frequency harmonic component in the ac source line current is

(A) 100 Hz (B) 150 Hz

(C) 250 Hz (D) 300 Hz

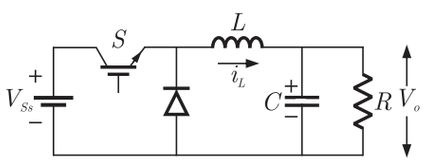
MCQ 1.9.83 A step-down chopper is operated in the continuous conduction mode is steady state with a constant duty ratio D. If V_0 is the magnitude of the dc output voltage and if V_s is the magnitude of the dc input voltage, the ratio V_0/V_s is given by

(A) D (B) $1 - D$

(C) $\frac{1}{1-D}$ (D) $\frac{D}{1-D}$

YEAR 2002 TWO MARKS

MCQ 1.9.84 In the chopper circuit shown in figure, the input dc voltage has a constant value V_s. The output voltage V_0 is assumed ripple-free. The switch S is operated with a switching time period T and a duty ratio D. What is the value of D at the boundary of continuous and discontinuous conduction of the inductor current i_L?



(A) $D = 1 - \frac{V_s}{V_0}$ (B) $D = \frac{2L}{RT}$

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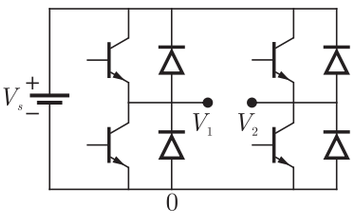
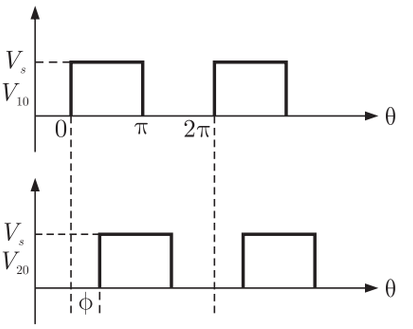
(C) $D = 1 - \dfrac{2L}{RT}$ (D) $D = \dfrac{RT}{L}$

MCQ 1.9.85 Figure(a) shows an inverter circuit with a dc source voltage V_s. The semiconductor switches of the inverter are operated in such a manner that the pole voltage V_{10} and V_{20} are as shown in figure(b). What is the rms value of the pole-to-pole voltage V_{12}?

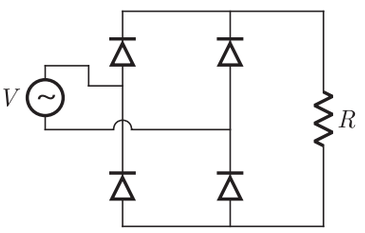




(A) $\dfrac{V_s \phi}{\pi\sqrt{2}}$ (B) $V_s\sqrt{\dfrac{\phi}{\pi}}$

(C) $V_s\sqrt{\dfrac{\phi}{2\pi}}$ (D) $\dfrac{V_s}{\pi}$

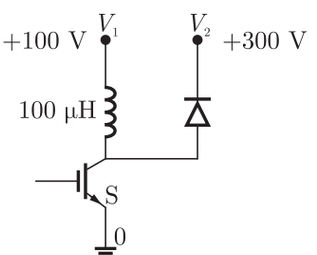
MCQ 1.9.86 In the single phase diode bridge rectifier shown in figure, the load resistor is $R = 50\,\Omega$. The source voltage is $V = 200\sin(\omega t)$, where $\omega = 2\pi \times 50$ radians per second. The power dissipated in the load resistor R is



(A) $\dfrac{3200}{\pi}$ W (B) $\dfrac{400}{\pi}$ W

(C) 400 W (D) 800 W

MCQ 1.9.87 *The semiconductor switch S in the circuit of figure is operated at a frequency of 20 kHz and a duty ratio $D = 0.5$. The circuit operates in the steady state. Calculate the power transferred from the dc voltage source V_2.



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MCQ 1.9.88 The main reason for connecting a pulse transformer at the output stage of thyristor triggering circuit is to

(A) amplify the power of the triggering pulse

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(B) provide electrical isolation

(C) reduce the turn on time of thyristor

(D) avoid spurious triggering of the thyristor due to noise

MCQ 1.9.89 AC-to-DC circulating current dual converters are operated with the following relationship between their triggering angles(α_1 and α_2)

(A) $\alpha_1 + \alpha_2 = 180^\circ$ (B) $\alpha_1 + \alpha_2 = 360^\circ$

(C) $\alpha_1 - \alpha_2 = 180^\circ$ (D) $\alpha_1 + \alpha_2 = 90^\circ$

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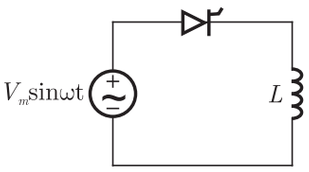
MCQ 1.9.90 A half-wave thyristor converter supplies a purely inductive load as shown in figure. If the triggering angle of the thyristor is 120°, the extinction angle will be



(A) 240° (B) 180°

(C) 200° (D) 120°

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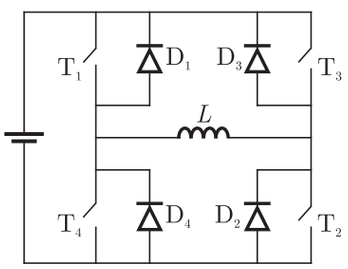
MCQ 1.9.91 A single-phase full bridge voltage source inverter feeds a purely inductive load as shown in figure, where T_1, T_2, T_3, T_4 are power transistors and D_1, D_2, D_3 , D_4 are feedback diodes. The inverter is operated in square-wave mode with a frequency of 50 Hz. If the average load current is zero, what is the time duration of conduction of each feedback diode in a cycle?



(A) 5 msec (B) 10 msec

(C) 20 msec (D) 2.5 msec

MCQ 1.9.92 *A voltage commutated thyristor chopper circuit is shown in figure. The chopper is operated at 500 Hz with 50% duty ratio. The load takes a constant current of 20 A.

(a) Evaluate the circuit turn off time for the main thyristor Th_1.

(b) Calculate the value of inductor L, if the peak current through the main thyristor Th_1 is limited to 180% of the load current.

(c) Calculate the maximum instantaneous output voltage of chopper.

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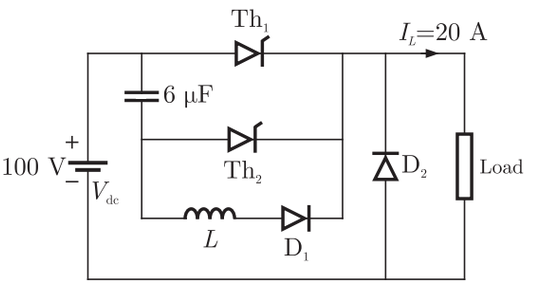
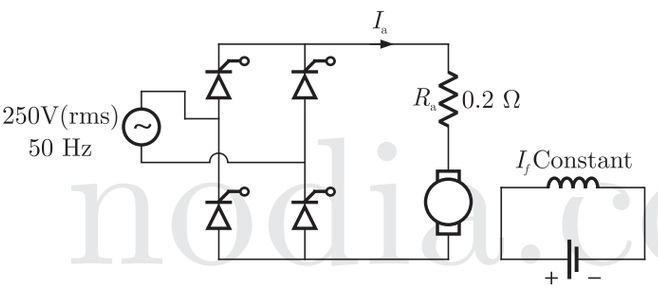


MCQ 1.9.93 *A separately excited dc motor is controlled by varying its armature voltage using a single-phase full-converter bridge as shown in figure. The field current is kept constant at the rated value. The motor has an armature resistance of 0.2 Ω, and the motor voltage constant is 2.5 V/(rad/sec). The motor is driving a mechanical load having a constant torque of 140 Nm. The triggering angle of converter is 60° . The armature current can be assumed to be continuous and ripple free.



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(a) Calculate the motor armature constant.

(b) Evaluate the motor speed in rad/sec.

(c) Calculate the rms value of the fundamental component of the input current to the bridge.

****

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SOLUTION

SOL 1.9.1 Option (C) is correct.

Given,

$$L = \frac{100}{\pi}\mu\text{H}$$

$$C = \frac{100}{\pi}\mu\text{F}$$

When the circuit is triggered by $10\,\mu s$ pulse, the thyristor is short circuited and so, we consider

$$I_C = I_m \sin \omega t$$

Therefore, voltage stored across capacitor is

$$V_C = \frac{1}{C}\int I_C\, dt$$

$$= V_m(1 - \cos \omega t)$$

where ω is angular frequency obtained as

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\left(\frac{100}{\pi}\right) \times 10^{-6}} = \pi \times 10^4$$

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So, $$T = \frac{1}{f} = \frac{2\pi}{\omega} = 200\,\mu s$$

As $I_C = I_m \sin \omega t$ oscillates between $-$ve and $-$ve half cycle so, circuit is conducting for only half of cycle and thyristor is open after half cycle.

i.e., the conduction period $= \frac{T}{2} = 100\,\mu s$

SOL 1.9.2 Option (D) is correct.

Given, the rated armature current

$$I_{a(rated)} = 20\text{ A}$$

as rated armature voltage

$$V_{a(rated)} = 150\text{ volt}$$

Also, for the armature, we have

$$L_a = 0.1\,\text{mH},\ R_a = 1\,\Omega$$

and $T = 50\%$ of T_{rated} (T → Torque)

So, we get

$$I = [I_{a(\text{rotated})}](0.5) = 10\text{ A}$$

$$N = N_{\text{rated}},$$

$$I_f = I_{f\,rated} \rightarrow \text{rated field current}$$

At the rated conditions,

$$E = V - I_{a(\text{rated})}R_a$$

$$= 150 - 20(1) = 130\text{ volt}$$

For given torque,

$$V = E + I_a R_a = 130 + (10)(1) = 140\text{ V}$$

Therefore, chopper output $= 140$ V

or, $$D(200) = 140$$

or, $$D = \frac{140}{200} = 0.7$$ (D → duty cycle)

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SOL 1.9.3 Option (C) is correct.

Here, as the current from source of 12 V is the same as that pass through inductor. So, the peak to peak current ripple will be equal to peak to peak inductor current. Now, the peak to peak inductor current can be obtained as

$$I_L \text{ (Peak to Peak)} = \frac{V_s}{L} D\, T_s$$

where, $V_s \rightarrow$ source voltage $= 12$ volt,

$L \rightarrow$ inductance $= 100\mu\text{H} = 10^{-4}\text{H}$,

$D \rightarrow$ Duty ration $= 0.4$,

$T_S \rightarrow$ switching time period of MOSFET $= \frac{1}{f_s}$

and $f_s \rightarrow$ switching frequency $= 250$ kHz

Therefore, we get

$$I_{L(\text{Peak to Peak})} = \frac{12}{10^{-4}} \times 0.4 \times \frac{1}{250 \times 10^3}$$
$$= 0.192 \text{ A}$$

This is the peak to peak source current ripple.

SOL 1.9.4 Option (B) is correct.

Here, the average current through the capacitor will be zero. (since, it is a boost converter). We consider the two cases :

Case I : When MOSFET is ON

$$i_{c_1} = -i_0 \qquad (i_0 \text{ is output current})$$

(since, diode will be in cut off mode)

Case II : When MOSFET is OFF

Diode will be forward biased and so

$$i_{c_1} = I_s - i_0 \qquad (I_s \text{ is source current})$$

Therefore, average current through capacitor

$$I_{c,avg} = \frac{i_{c_1} + I_{c_2}}{2}$$

$$\Rightarrow \quad 0 = \frac{DT_s(-i_o) + (1-D)T_s(I_s - i_o)}{2} \quad (D \text{ is duty ratio})$$

Solving the equation, we get

$$I_s = \frac{i_0}{(1-D)} \qquad \ldots(1)$$

Since, the output load current can be given as

$$i_0 = \frac{V_0}{R} = \frac{V_s/_{1-D}}{R} = \frac{12/0.6}{20} = 1\text{A}$$

Hence, from Eq. (1)

$$I_s = \frac{i_0}{1-D} = \frac{1}{0.6} = \frac{5}{3}\text{A}$$

SOL 1.9.5 Option (D) is correct.

We consider the following two cases :

Case I : When Q_1, Q_2 ON

In this case the +ve terminal of V_0 will be at higher voltage. i.e. $V_0 > 0$ and so $i_0 > 0$ (i.e., it will be +ve). Now, when the Q_1, Q_2 goes to OFF condition we consider the second case.

Case II : When Q_3, Q_4 ON and Q, Q_2 OFF :

In this condition, −ve terminal of applied voltage V_0 will be at higher potential i.e., $V_0 < 0$ and since, inductor opposes the change in current so, although the

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polarity of voltage V_0 is inversed, current remains same in inductor i.e. $I_0 > 0$. This is the condition when conduction have been asked.

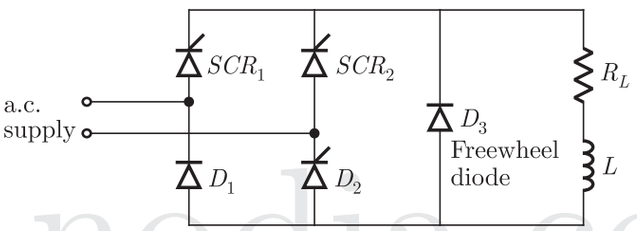
In this condition $(V_0 > 0, I_0 > 0)$ since, IGBT's can't conduct reverse currents therefore current will flow through D_3, D_4 until I_D becomes negative. Thus, D_3 and D_4 conducts.

SOL 1.9.6 Option (D) is correct.

When Q_3, Q_4 is switched ON, initially due to the reverse current it remain in OFF state and current passes through diode. In this condition the voltage across Q_3 and Q_4 are zero as diodes conduct. Hence, it shows zero voltage switching during turn-ON

SOL 1.9.7 Option (D) is correct.

The circuit of a single-phase half controlled bridge rectifier with RL load and free wheel diode is shown as below.



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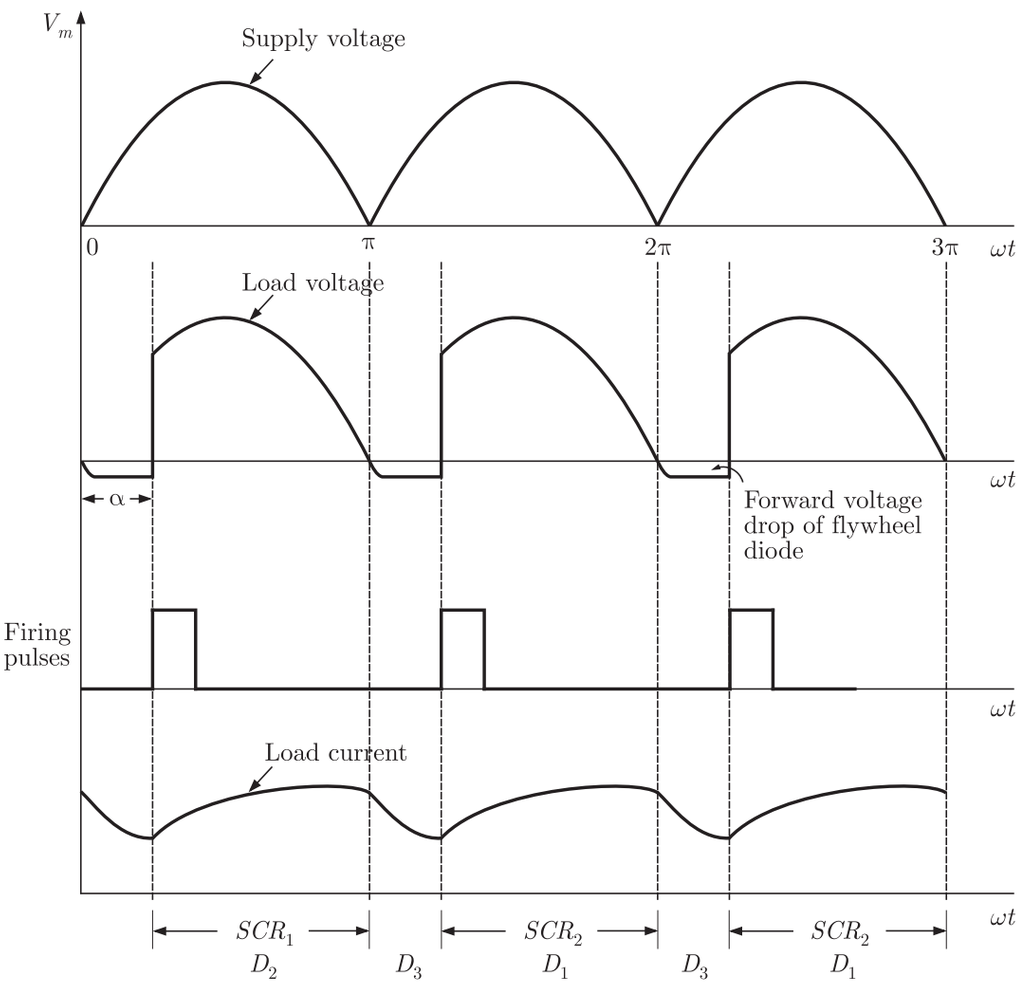
The voltage current wave forms are shown in figure below.



We note that, for continuous load current, the flywheel diode conducts from π

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to $\pi + \alpha$ in a cycle. Thus, fraction of cycle that freewheel diode conducts is α/π. Thus fraction of cycle that freewheel diode conducts is α/π.

SOL 1.9.8 Option (B) is correct.
The latching current is higher than the holding current. Usually, latching current is taken two to three times the holding currents.

SOL 1.9.9 Option (C) is correct.

$$I_S = I_0 + \frac{\Delta i_c}{2} = 5 + 0.8 = 5.8\ \text{A}$$

SOL 1.9.10 Option (B) is correct.
For a three-phase bridge inverter, rms value of output line voltage is

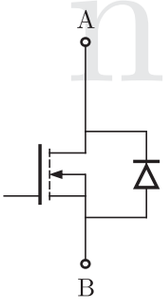
$$V_L = \frac{\sqrt{2}}{3} V_{dc} = \frac{\sqrt{2}}{3} \times 300 \qquad V_{dc} = 300\ \text{V}$$

$$= 141.4\ \text{V}$$

SOL 1.9.11 Option (D) is correct.

$$P = 3 \times \frac{V_L^2}{R} = 3 \times \frac{(141.4)^2}{20} \simeq 3\ \text{kW}$$

SOL 1.9.12 Option (C) is correct.
Only option C allow bi direction power flow from source to the drive



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SOL 1.9.13 Option (C) is correct.
Once the SCR start conducting by an forward current, the gate has no control on it and the device can be brought back to the blocking state only by reducing the forward current to a level below that of holding current. This process of turn-off is called commutation. This time is known as the circuit turn-off time of an SCR.

SOL 1.9.14 Option (A) is correct.
Maximum current through main thyristor

$$I_M(\max) = I_0 + V_s\sqrt{\frac{C}{L}} = 10 + 200\sqrt{\frac{0.1 \times 10^{-6}}{1 \times 10^3}} = 12\ \text{A}$$

Maximum current through auxiliary thyristor

$$I_A(\max) = I_0 = 10\ \text{A}$$

SOL 1.9.15 Option (A) is correct.
Output voltage of 3-phase bridge converter

$$V_0 = \frac{3\sqrt{3}}{\pi} V_{ph} \cos\alpha$$

Maximum output

$$(V_0)_{\max} = \frac{3\sqrt{3}}{\pi} V_{ph} \quad \cos\alpha = 1$$

$$= \frac{3\sqrt{3}}{\pi} \times \frac{400 \times \sqrt{2}}{\sqrt{3}}$$

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$$= 540.6 \text{ V}$$

Resistance of filter choke is $10\,\Omega$, So

$$(V_0)_{\max} = E + IR_{\text{chock}}$$
$$540.6 = 400 + I(10)$$
$$I \simeq 14 \text{ A}$$

SOL 1.9.16 Option (D) is correct.

$$\text{kVA rating} = \sqrt{3}\, V_L I_L = \sqrt{3} \times 400 \times \frac{\sqrt{6}}{\pi} \times 14$$
$$= 7.5 \text{ kVA}$$

SOL 1.9.17 Option (A) is correct.

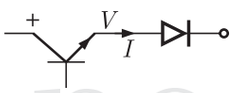
The figure shows a step down chopper circuit.

$\because$ $V_{\text{out}} = DV_{\text{in}}$

where, $D =$ Duty cycle and $D < 1$

SOL 1.9.18 Option (C) is correct.

Given figure as



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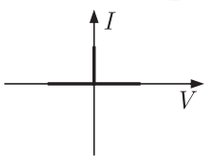
The I-V characteristic are as



Since diode connected in series so I can never be negative.

When current flows voltage across switch is zero and when current is zero than there may be any voltage across switch.

SOL 1.9.19 Option (A) is correct.

Given fully-controlled thyristor converter, when firing angle $\alpha = 0$, dc output voltage $V_{dc_0} = 300$ V

If $\alpha = 60^\circ$, then $V_{dc} = ?$

For fully-controlled converter

$$V_{dc_0} = \frac{2\sqrt{2}\, V_{dc_1}}{\pi} \cos\alpha$$

$\because$ $\alpha = 0$, $V_{dc_0} = 300$ V

$$300 = \frac{2\sqrt{2}\, V_{dc_1}}{\pi} \cos 0^\circ$$

$$V_{dc_1} = \frac{300\pi}{2\sqrt{2}}$$

At $\alpha = 60^\circ$, $V_{dc_2} = ?$

$$V_{dc_2} = \frac{2\sqrt{2}}{\pi} \times \frac{300\pi}{2\sqrt{2}} \cos 60^\circ = 300 \times \frac{1}{2} = 150 \text{ V}$$

SOL 1.9.20 Option (C) is correct.

SCR has the property that it can be turned ON but not OFF with a gate pulse, So SCR is being considered to be a semi-controlled device.

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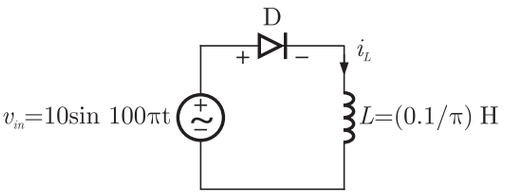
SOL 1.9.21 Option (D) is correct.



Current wave form for i_L

$$v_L = \frac{L di_L}{dt}$$

$$i_L = \frac{1}{2}\int v_L dt$$

for $0 < \omega_t \angle \pi$, $\quad v_L = v_{in} = 10 \sin \omega t = \frac{di_L}{dt}$

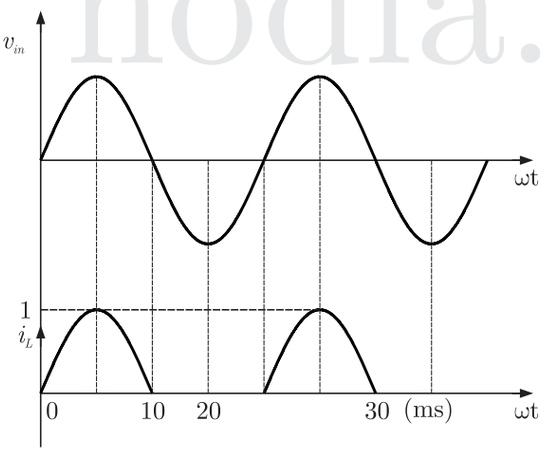
$$i_L = \frac{1}{2}\int v_L dt = -\cos 100\pi t + C$$

at $100\pi t = \pi/2$, $\quad i_L = 0, C = 0$

$$i_L = -100 \cos \pi t$$

$$i_{L(\text{peak})} = 1 \text{ Amp}$$

for $\pi < \omega t \; v_L = v_{in} = 0$



SOL 1.9.22 Option (C) is correct.

In CSI let T_3 and T_4 already conducting at $t = 0$

At triggering T_1 and T_2, T_3 and T_4 are force cumulated.

Again at $t = \frac{T}{2}$, T_1 and T_2 are force cumulated. This completes a cycle.

Time constant $\tau = RC = 4 \times 0.5 = 2$ μsec

Frequency $f = \frac{1}{\tau} = \frac{1}{2 \times 10^{-6}} = 500$ kHz

SOL 1.9.23 Option (A) is correct.

duty ratio $T_M = 0.8$

Maximum $\frac{dv}{dt}$ on $T_M = 50$ V/μsec

Minimum value of C_1 = ?

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Given that current ripple through L_0 is negligible.

Current through $T_M = I_m$ = duty ratio × current

$$= 0.8 \times 12.5 = 10 \text{ A}$$

$$\because \quad I_m = C_1 \frac{dv}{dt}$$

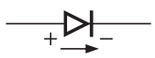
$$10 = C_1 \times \frac{50}{10^{-6}}$$

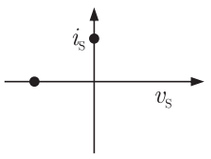
$$C_1 = \frac{50}{10} \times 10^{-6} = 0.2 \ \mu\text{F}$$

SOL 1.9.24 Option (C) is correct.

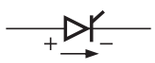
Characteristics are as

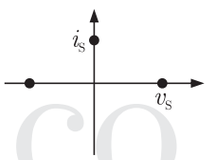
(P)



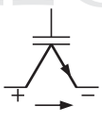


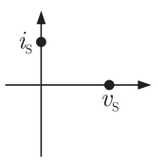
(Q)



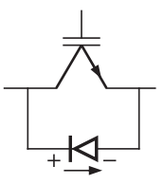


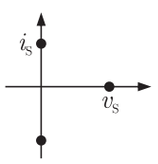
(R)



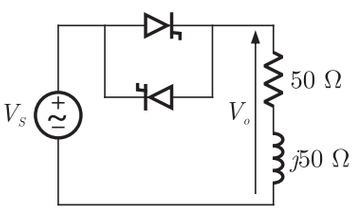


(S)





SOL 1.9.25 Option (A) is correct.



$$R + jXL = 50 + 50j$$

$$\therefore \quad \tan\phi = \frac{\omega L}{R} = \frac{50}{50} = 1$$

$$\phi = 45^\circ$$

so, firing angle 'α' must be higher the 45°, Thus for $0 < \alpha < 45^\circ$, V_0 is uncontrollable.

SOL 1.9.26 Option (D) is correct.

A 3-ϕ voltage source inverter is operated in 180° mode in that case third harmonics

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are absent in pole voltage and line voltage due to the factor $\cos(n\pi/6)$. so both are free from 3rd harmonic components.

SOL 1.9.27 Option (B) is correct.

In this case $$f = \frac{1}{T_{ON_1} + T_{ON_2}}$$

and, $$D = \frac{T_{ON_2}}{T_{ON_1} + T_{ON_2}}$$

SOL 1.9.28 Option (B) is correct.

Given $\alpha = 30^\circ$, in a 1-ϕ fully bridge converter

we know that,

$$\text{Power factor} = \text{Distortion factor} \times \cos\alpha$$

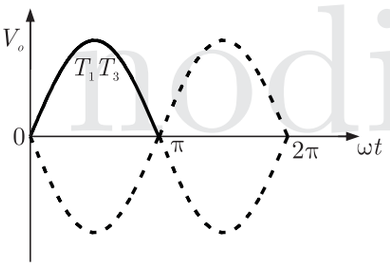
$$\text{D.f. (Distortion factor)} = I_{s(\text{fundamental})}/I_s = 0.9$$

$$\text{power factor} = 0.9 \times \cos 30^\circ$$

$$= 0.78$$

SOL 1.9.29 Option (A) is correct.

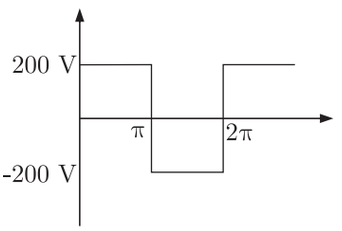
Output of this



Here the inductor makes T_1 and T_3 in ON because current passing through T_1 and T_3 is more than the holding current.

SOL 1.9.30 Option (C) is correct.

Input is given as



Here load current does not have any dc component

$\therefore$ Peak current occur at (π/ω)

$\therefore$ $$V_s = L\frac{di}{dt}$$

$$200 = 0.1 \times \frac{di}{dt}$$

Here $$di = \left(\frac{\pi}{2\pi}\right)\left(\frac{1}{50}\right) = \frac{1}{100}$$

So $$di_{(\max)} = 200 \times \frac{1}{100} \times \frac{1}{0.1} = 20 \text{ A}$$

SOL 1.9.31 Option (C) is correct.

Here for continuous conduction mode, by Kirchoff's voltage law, average load

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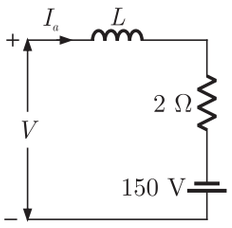
current



$$V - 2I_a + 150 = 0$$

$$I_a = \frac{V + 150}{2}$$

$\therefore I_1 = 10$ A, So

$$V = -130 \text{ V}$$

$$\frac{2V_m}{\pi}\cos\alpha = -130$$

$$\frac{2 \times \sqrt{2} \times 230}{\pi}\cos\alpha = -130^\circ$$

$$\alpha = 129^\circ$$

SOL 1.9.32 Option (B) is correct.

$$\text{Total rms current } I_a = \sqrt{\frac{2}{3}} \times 10 = 8.16 \text{ A}$$

$$\text{Fundamental current } I_{a1} = 0.78 \times 10 = 7.8 \text{ A}$$

$$\text{THD} = \sqrt{\frac{1}{\text{DF}^2} - 1}$$

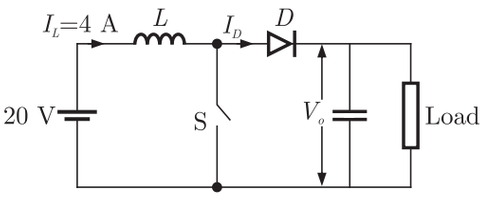
where

$$\text{DF} = \frac{I_{a1}}{I_a} = \frac{0.78 \times 10}{0.816 \times 10} = 0.955$$

$\therefore$

$$\text{THD} = \sqrt{\left(\frac{1}{0.955}\right)^2 - 1} = 31\%$$

SOL 1.9.33 Option (C) is correct.



In the given diagram
when switch S is open $I_0 = I_L = 4$ A, $V_s = 20$ V
when switch S is closed $I_D = 0, V_0 = 0$ V
Duty cycle $= 0.5$ so average voltage is $\frac{V_s}{1 - \delta}$

$$\text{Average current} = \frac{0 + 4}{2} = 2 \text{ amp}$$

$$\text{Average voltage} = \frac{20}{1 - 0.5} = 40 \text{ V}$$

SOL 1.9.34 Option (A) is correct.

Firing angle $\alpha = 25^\circ$

Overlap angle $\mu = 10^\circ$

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so, $$I_0 = \frac{V_m}{\omega Ls}[\cos\alpha - \cos(\alpha+\mu)]$$

$$\therefore \quad 20 = \frac{230\sqrt{2}}{2\pi \times 50 Ls}[\cos 25^\circ - \cos(25^\circ + 10^\circ)]$$

$$\therefore \quad Ls = 0.0045 \text{ H}$$

$$V_0 = \frac{2V_m \cos\alpha}{\pi} - \frac{\omega Ls I_0}{\pi}$$

$$= \frac{2 \times 230\sqrt{2}\cos 25^\circ}{3.14} - \frac{2 \times 3.14 \times 50 \times 4.5 \times 10^{-3} \times 20}{3.14}$$

$$= 187.73 - 9 = 178.74^\circ$$

$$\text{Displacement factor} = \frac{V_0 I_0}{V_s I_s} = \frac{178.25 \times 20}{230 \times 20} = 0.78$$

SOL 1.9.35 Option (C) is correct.

Given that

$$P = 50 \times 1000 \text{ W}$$

$$V_d = 420$$

So $$P = V_d \times I_d$$

$$I_d = \frac{50 \times 1000}{420} = 119.05$$

$$\text{RMS value of thyristor current} = \frac{119.05}{\sqrt{3}} = 68.73$$

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SOL 1.9.36 Option (B) is correct.

Single phase full wave half controlled bridge converter feeds an Inductive load. The two SCRs in the converter are connected to a common dc bus. The converter has to have free wheeling diode because the converter does not provide for free wheeling for high values of triggering angles.

SOL 1.9.37 Option (D) is correct.

If we connect the MOSFET with the VSI, but the six MOSFETs are connected in bridge configuration, in that case they also operated as constant current sources in the saturation region so this statement is false.

SOL 1.9.38 Option (C) is correct.

Given that, total harmonic distortion

$$\text{THD} = \frac{\sqrt{V_{rms^2} - V_1^2}}{V_1} \times 100$$

Pulse width is 150°

Here $$V_{\text{rms}} = \left(\sqrt{\frac{150}{180}}\right)V_s = 0.91 V_s$$

$$V_1 = V_{\text{rms(fundamental)}} = \frac{0.4 V_s}{\pi \times \sqrt{2}} \sin 75^\circ = 0.8696 V_s$$

$$\text{THD} = \sqrt{\frac{(0.91V_s)^2 - (0.87V_s)^2}{(0.87V_s)^2}} = 31.9\%$$

SOL 1.9.39 Option (A) is correct.

When losses are neglected,

$$\frac{3 \times \sqrt{2} \times 440}{\pi}\cos\alpha = K_m \times \frac{750 \times 2\pi}{60}$$

Here back emf ε with ϕ is constant

$$\varepsilon = V_0 = K_m \omega_m$$

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$$440 = K_m \times \frac{1500 \times 2\pi}{60}$$

$$K_m = 2.8$$

$$\cos\alpha = 0.37$$

at this firing angle

$$V_t = \frac{3\sqrt{2} \times 440}{\pi} \times (0.37) = 219.85 \text{ V}$$

$$I_a = \frac{1500}{440} = 34.090$$

$$I_{sr} = I_a\sqrt{2/3} = 27.83$$

$$\text{p.f.} = \frac{V_t I_s}{\sqrt{3}\, V_s I_{sr}} = 0.354$$

SOL 1.9.40 Option (D) is correct.

$$V_s = \frac{230}{4} = 57.5$$

Here charging current $= I$

$$V_m \sin\theta = 12$$

$$\theta_1 = 8.486 = 0.148 \text{ radian}$$

$$V_m = 81.317 \text{ V}$$

$$\varepsilon = 12 \text{ V}$$

There is no power consumption in battery due to ac current, so average value of charging current.

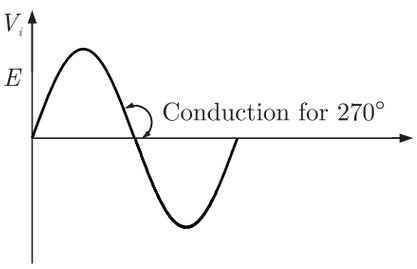
$$I_{av(\text{charging})} = \frac{1}{2\pi \times 19.04}[2V_m \cos\theta_1 - \varepsilon(\pi - 2\theta_1)]$$

$$= \frac{1}{2\pi \times 19.04}[2 \times V_m \times \cos\theta_1 - 12(\pi - 2\theta_1)]$$

$$= 1.059\ \Omega/\text{A}$$

SOL 1.9.41 Option (C) is correct.

Conduction angle for diode is 270° as shown in fig.



SOL 1.9.42 Option ( ) is correct.

SOL 1.9.43 Option (C) is correct.

Here, V_m = maximum pulse voltage that can be applied

so $= 10 - 1 - 1 - 1 = 7$ V

Here 1 V drop is in primary transistor side, so that we get 9V pulse on the secondary side. Again there are 1 V drop in diode and in gate cathode junction each.

$$I_{g\,\max} = 150 \text{ mA}$$

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So $R = \dfrac{V_m}{I_{g\,\max}} = \dfrac{7}{150\text{ mA}} = 46.67\ \Omega$

SOL 1.9.44 Option (A) is correct.

We know that the pulse width required is equal to the time taken by i_a to rise upto i_L

so, $V_s = L\dfrac{di}{dt} + R_i\,(V_T \approx 0)$

$$i_a = \frac{200}{1}[1 - e^{-t/0.15}]$$

Here also $t = T$, $i_a = i_L = 0.25$

$$0.25 = 200[1 - e^{-T/0.5}]$$

$$T = 1.876 \times 10^{-4} = 187.6\ \mu\text{s}$$

Width of pulse $= 187.6\ \mu\text{s}$

Magnitude of voltage $= 10$ V

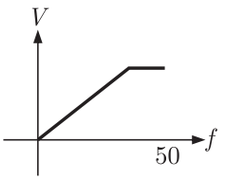
V_{sec} rating of P.T. $= 10 \times 187.6\ \mu\text{s}$

$= 1867\ \mu\text{V-s}$ is approx to $2000\ \mu\text{V-s}$

SOL 1.9.45 Option (D) is correct.

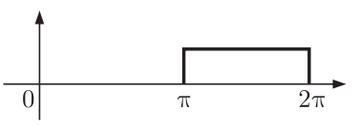
If we varying the frequency for speed control, V/f should be kept as constant so that, minimum flux density (B_m) also remains constant

So, $V = 4.44NB_m\text{A}f$



SOL 1.9.46 Option (D) is correct.

In first half cycle D_1 will conduct and D_2 will not and at $\theta = 0$ there is zero voltage. So current wave form is as following



SOL 1.9.47 Option (B) is correct.

In the PWM inverter

$V_0 =$ output voltage of inverter

$$V_0 = \sum_{n=1}^{\infty} \frac{4V_s}{n\pi} \sin nd\ \sin n\omega t\ \sin n\pi/2$$

So the pulse width $= 2d = 144^\circ$

$$V_{01} = \frac{4V_s}{\pi} \sin 72^\circ \sin \omega t$$

$$V_{03} = \frac{4V_s}{3\pi} \sin(3 \times 72^\circ) \sin 3\omega t$$

so, $$\left(\frac{V_{03}}{V_{01\max}}\right) = \frac{\dfrac{4V_s}{3\pi} \times \sin(3 \times 72^\circ)}{\dfrac{4V_s}{\pi} \sin 72^\circ} = 19.61\%$$

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SOL 1.9.48 Option (C) is correct.

Given that

400 V, 50 Hz AC source, $\alpha = 60^\circ$, $I_L = 10$ A

so,

$$\text{Input displacement factor} = \cos\alpha = 0.5$$

and, $$\text{input power factor} = \text{D.F.} \times \cos\alpha$$

$$\text{distortion factor} = \frac{I_{s(\text{fundamental})}}{I_s} = \frac{\frac{4 \times 10}{\pi \times \sqrt{2}} \sin 60^\circ}{10 \times \sqrt{2/3}}$$

$$= 0.955$$

so, $$\text{input power factor} = 0.955 \times 0.5 = 0.478$$

SOL 1.9.49 Option (A) is correct.

We know that

$$T = RC \ln 2$$

So $$C = \frac{T}{R \times 0.693} = \frac{100}{50 \times 0.693} = 2.88\ \mu\text{F}$$

SOL 1.9.50 Option (A) is correct.

Let we have

$$R_{\text{solar}} = 0.5\,\Omega,\ I_0 = 20\ \text{A}$$

so $$V_s = 350 - 20 \times 0.5 = 340\ \text{V}$$

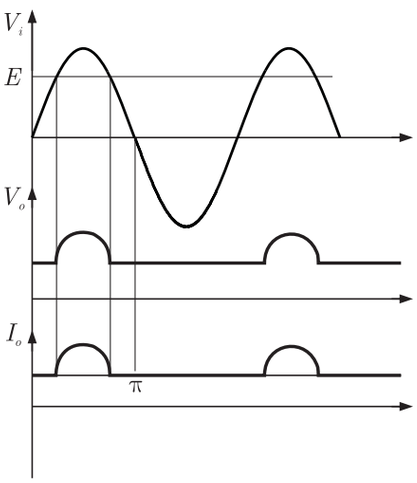
$\therefore$ $$340 = \frac{3 \times 440 \times \sqrt{2}}{\pi} \cos\alpha$$

$$\cos\alpha = 55^\circ$$

So each thyristor will reverse biased for $180^\circ - 55^\circ = 125^\circ$.

SOL 1.9.51 Option (C) is correct.

In this circuitry if SCR gets open circuited, than circuit behaves like a half wave rectifier.



So

$$I_{\text{avg}} = \text{Average value of current}$$

$$= \frac{1}{2\pi R} \int_{\theta_1}^{\pi - \theta_1} (V_m \sin\omega t - E)\, d\theta$$

$\because$ $$I_{0(\text{avg})} = \frac{1}{2\pi R}[2V_m \cos\theta - E(\pi - 2\theta_1)]$$

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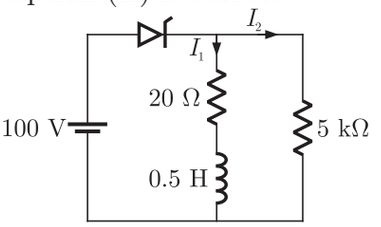
$$= \frac{1}{2\pi \times 2}[2 \times (230 \times \sqrt{2})\cos\theta - 200(\pi - 2\theta_1)]$$

$$\theta_1 = \sin^{-1}\left(\frac{E}{V_m}\right) = \sin^{-1}\left(\frac{200}{230 \times \sqrt{2}}\right) = 38^\circ = 0.66 \text{ Rad}$$

$$\therefore \quad I_{0(\text{avg})} = \frac{1}{2\pi \times 2}[2\sqrt{2} \times 230\cos 38^\circ - 200(\pi - 2 \times 0.66)]$$

$$= 11.9 \text{ A}$$

SOL 1.9.52 Option (B) is correct.



In this given circuit minimum gate pulse width time= Time required by i_a rise up to i_L

$$i_2 = \frac{100}{5 \times 10^3} = 20 \text{ mA}$$

$$i_1 = \frac{100}{20}[1 - e^{-40t}]$$

$$\therefore \quad \text{anode current } I = I_1 + I_2 = 0.02 + 5[1 - e^{-40t}]$$

$$0.05 = 0.05 + 5[1 - e^{-40t}]$$

$$1 - e^{-40t} = \frac{0.03}{5}$$

$$T = 150 \text{ μs}$$

SOL 1.9.53 Option (B) is correct.

Given $I_L = 10$ A. So in the +ve half cycle, it will charge the capacitor, minimum time will be half the time for one cycle.

so min time required for charging

$$= \frac{\pi}{\omega_0} = \pi\sqrt{LC}$$

$$= 3.14 \times \sqrt{2 \times 10^{-3} \times 10^{-6}} = 140 \text{ μsec}$$

SOL 1.9.54 Option (C) is correct.

Given $T_{\text{on}} = 140$ μsec

$$\text{Average output} = \frac{T_{\text{on}}}{T_{\text{total}}} \times V$$

$$T_{\text{total}} = 1/f = \frac{1}{103} = 1 \text{ msec}$$

$$\text{so average output} = \frac{140 \times 10^{-6}}{1 \times 10^{-3}} \times 250 = 35 \text{ V}$$

SOL 1.9.55 Option (A) is correct.

The conduction loss v/s MOSFET current characteristics of a power MOSFET is best approximated by a parabola.

SOL 1.9.56 Option (B) is correct.

In a 3-ϕ bridge rectifier

$$V_{\text{rms}} = 400 \text{ V}, \ f = 50 \text{ Hz}$$

This is purely resistive then

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instantaneous voltage $V_0 = \sqrt{2}\, V_{\text{rms}} = 400\sqrt{2}$ V

SOL 1.9.57 Option (C) is correct.
A 3-ϕ square wave (symmetrical) inverter contains only odd harmonics.

SOL 1.9.58 Option (A) is correct.
In Ideal condition we take voltage across the device is zero.
average power loss during switching $= \frac{VI}{2}(t_1 + t_2)$ (turn ON)

SOL 1.9.59 Option (C) is correct.
So in P thyristor blocks voltage in both polarities until gate is triggered and also in R transistor along with diode can do same process.

SOL 1.9.60 Option (C) is correct.

$$\text{Duty ratio } \alpha = 0.5$$

here
$$T = \frac{1}{1 \times 10^{-3}} = 10^{-3} \text{ sec}$$
$$T_a = \frac{L}{R} = \frac{200 \text{ mH}}{5} = 40 \text{ msec}$$
$$\text{Ripple} = \frac{V_s}{R}\left[\frac{(1 - e^{-\alpha T/T_s})(1 - e^{-(1-\alpha)T/T_a})}{1 - e^{-T/T_s}}\right]$$
$$(\Delta I)_{\max} = \frac{V_s}{4fL} = \frac{100}{4 \times 10^3 \times 200 \times 10^{-3}}$$
$$= 0.125 \text{ A}$$

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SOL 1.9.61 Option (C) is correct.

$$T_{\text{st}} = 15 \text{ Nm}$$
$$T_L = 7 \text{ Nm}$$
$$\alpha = 2 \text{ rad/sec}^2$$
$$T = I\alpha$$

so
$$T = T_{\text{st}} - T_L = 8 \text{ Nm}$$
$$I = \frac{8}{2} = 4 \text{ kgm}^2$$

SOL 1.9.62 Option (B) is correct.

We know that $V_{\text{rms}} = 230$ V

so, $V_m = 230 \times \sqrt{2}$ V

If whether $\alpha < 90^\circ$

Then $V_{\text{peak}} = V_m \sin\alpha = 230$

$$230\sqrt{2}\sin\alpha = 230$$
$$\sin\alpha = \frac{1}{\sqrt{2}}$$
$$\text{angle } \alpha = 135^\circ$$

SOL 1.9.63 Option (D) is correct.
When we use BJT as a power control switch by biasing it in cut-off region or in the saturation region. In the on state both the base emitter and base-collector junction are forward biased.

SOL 1.9.64 Option (A) is correct.
Peak Inverse Voltage (PIV) across full wave rectifier is $2V_m$

$$V_m = 50\sqrt{2} \text{ V}$$

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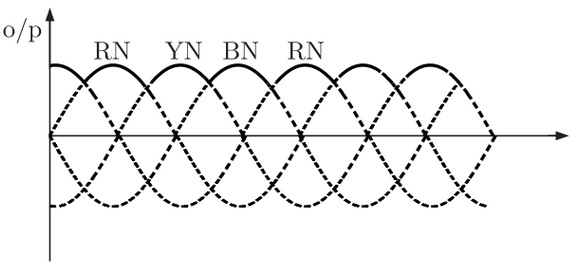
so, $\text{PIV} = 100\sqrt{2}\ \text{V}$

SOL 1.9.65 Option (D) is correct.

$$V_b = 12 \pm 4\ \text{V}$$
$$V_{b\max} = 16\ \text{V}$$
$$V_{b\min} = 8\ \text{V}$$
$$\text{Required value of } R = \frac{V_b(\min)}{I_g} = \frac{8}{10 \times 10^{-3}} = 800\ \Omega$$

SOL 1.9.66 Option (C) is correct.



$$\text{Ripple frequency} = 3f = 3 \times 400 = 1200\ \text{Hz}$$

So from V_0 ripple frequency $= 1200$ Hz

SOL 1.9.67 Option (C) is correct.

Given that $R = 0.15\ \Omega$

$I = 15$ A

$$\text{So average power losses} = \frac{1}{(2\pi/\omega)}\int_0^{\pi/\omega} I^2 R dt$$
$$= \frac{\omega}{2\pi} \times 10^2 \times 0.15 \times \pi/\omega$$
$$= 7.5\ \text{W}$$

SOL 1.9.68 Option (D) is correct.

Output dc voltage across load is given as following

$$V_{dc} = \sqrt{2}\,V\left[\frac{1}{\alpha\pi}\left\{(2\pi - \alpha) + \frac{\sin 2\alpha}{2}\right\}\right]^{\frac{1}{2}}$$
$$= \sqrt{2} \times 230\sqrt{2}\left[\frac{1}{\frac{\pi}{4} \times \pi}\left\{\left(2\pi - \frac{\pi}{4}\right) + \left(\frac{\sin \pi/2}{2}\right)\right\}\right]^{\frac{1}{2}}$$
$$= 317.8\ \text{V}$$
$$\text{losses} = \frac{V_{dc}^2}{R} = \frac{(317.8)^2}{100} = 10100\ \text{W}$$

SOL 1.9.69 Option (C) is correct.

$V_s = 100$ V, duty ratio $= 0.8$, $R = 10\ \Omega$

$$\text{So average current through diode} = \frac{\alpha V_s}{R}$$
$$= \frac{0.8 \times 100}{10} = 8\ \text{A}$$

SOL 1.9.70 Option (D) is correct.

Peak current through S_1

$$I = I_0 + V_S\sqrt{C/L} = 20 + 200\sqrt{\frac{2 \times 10^{-6}}{200 \times 10^{-6}}} = 40\ \text{A}$$

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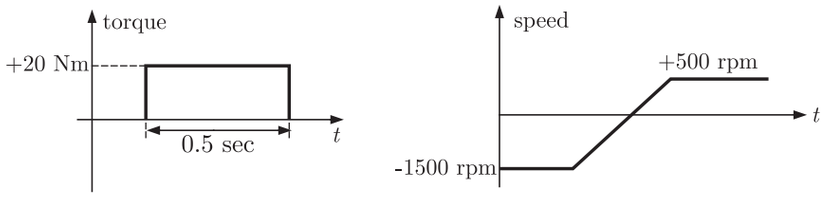
SOL 1.9.71 Option ( ) is correct.

SOL 1.9.72 Option (C) is correct.



so

$$\alpha = \left[\frac{500-(-1500)}{0.5}\right] \times \frac{2\pi}{60} = 418.67 \text{ rad/sec}^2$$

and $T = 40$ Nm

$$T = I\alpha$$

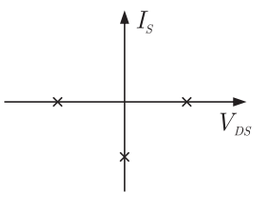
$$I = \frac{T}{\alpha} \times \frac{40}{418.67} = 0.096 \text{ kgm}^2$$

SOL 1.9.73 Option (D) is correct.

When thyristor turned on at that time J2 junction will break. So J1, J2, J3 all are in forward bias.

SOL 1.9.74 Option (D) is correct.

The ON-OFF state of switch is given on $V_{DS} - I_S$ plane as following



When $V_{DS} = +$ ve, diode conducts and $I_S = 0$

$V_{DS} = -$ ve, diode opens, but $I_S = 0$, D $\rightarrow -$ ve potential.

SOL 1.9.75 Option (B) is correct.

P. Field control-Above base speed

Q. Armature control-below base torque

SOL 1.9.76 Option (A) is correct.

As we know in fully controlled rectifier.

$$V_{PP} = V_m - V_m \cos(\pi/6 + \alpha) \qquad \because \alpha = 30^\circ$$

or $$V_{PP} = V_m[1 - \cos(\pi/6 + 30^\circ)]$$

or $$\frac{V_{PP}}{V_m} = 0.5$$

SOL 1.9.77 Option ( ) is correct.

SOL 1.9.78 Option (A) is correct.

In the chopper during turn on of chopper V-t area across L is,

$$\int_0^{T_{on}} V_L\, dt = \int_0^{T_{on}} L\left(\frac{di}{dt}\right) dt = \int_{i_{min}}^{i_{max}} L\, di$$

$$= L(i_{max} - i_{min}) = L(\Delta I)$$

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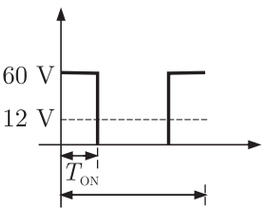
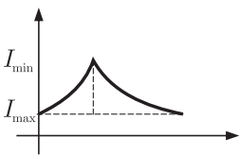




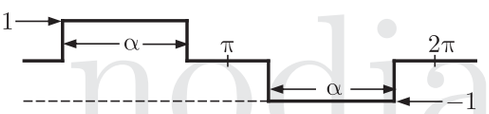
V-t are applied to 'L' is $= (60 - 12)\, T_{on}$

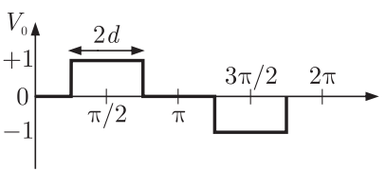
$$= 48 T_{on}$$

So now volt area

$$\Delta I = \frac{48 T_{on}}{L} = \frac{48 \times 0.2 \times 10^{-3}}{20 \times 10^{-3}} = 0.48 \text{ A}$$

SOL 1.9.79 Option (A) is correct.





Output voltage $V_0 = \sum_{n=1,3,5}^{\infty} \left(\frac{4V_S}{n\pi}\right)(\sin nd)(\sin n\omega t)(\sin n\pi/2)$

$\therefore$ RMS value of fundamental component

$$V_{rms(\text{fundamental})} = \frac{4V_S}{\sqrt{2}\,\pi} \sin d \times 1$$

$\alpha = 120^\circ,\ 2d = 120^\circ \Rightarrow d = 60^\circ$

$$V_{rms(\text{fundamental})} = \frac{4V_S}{\sqrt{2}\,\pi} \times \sin 60^\circ$$

$$= 0.78 V_S = 0.78 \text{ V}$$

SOL 1.9.80 Option (A) is correct.

After removing 5^{th} harmonic

$$5d = 0, \pi, 2\pi$$

$\therefore$ Pulse width $= 2d = \alpha = 0, \frac{2\pi}{5}, \frac{4\pi}{5}$

$$= 0^\circ, 72^\circ, 144^\circ$$

SOL 1.9.81 Option (C) is correct.

$$N_{Sa} = 3000 \text{ rpm}$$

$$N_a = 2850 \text{ rpm}$$

$$S_{FL} = \frac{3000 - 2850}{3000} = 0.05$$

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where by (V/f) control

$$N_{sb} = 3000\left(\frac{40}{50}\right) = 2400 \text{ rpm}$$

$$\therefore \quad N_2 = \text{new running speed of motor}$$

$$= 2400\left(1 - \frac{0.05}{2}\right) = 2340 \text{ rpm}$$

SOL 1.9.82 Option (C) is correct.

For six pulse thyristor rectifier bridge the lowest frequency component in AC source line current is of 250 Hz.

SOL 1.9.83 Option (A) is correct.

Given a step down chopper is operated in continuous conduction mode in steady state with a constant duty Ratio D.

$V_0 \rightarrow$ dc output voltage.

$V_s \rightarrow$ dc input voltage

$$\frac{V_0}{V_s} = D = \text{duty ratio}$$

SOL 1.9.84 Option ( ) is correct.

SOL 1.9.85 Option (B) is correct.

From figure

$$(V_{12})_{\text{rms}} = \left[\frac{1}{\pi}\int_0^{\phi} V_s^2 d\omega\right]^{1/2}$$

$$= \frac{V_s}{\sqrt{\pi}} \times \sqrt{\phi} = V_s\sqrt{\frac{\phi}{\pi}}$$

SOL 1.9.86 Option (C) is correct.

Given that, $V = 200\sin\omega t$

$$f = 50 \text{ Hz}$$

Power dispatched in the load resistor $R = ?$

First we have to calculate output of rectifier.

$$(V_0)_{\text{rms}} = \left[\frac{1}{\pi}\int_0^{\pi}(200\sin\omega t)^2 d\omega t\right]^{1/2}$$

$$= \frac{200}{\sqrt{\pi}}\left[\int_0^{\pi}\left(\frac{1-\cos 2\omega t}{2}\right)d\omega t\right]^{1/2}$$

$$= \frac{200}{\sqrt{\pi}}\left[\frac{1}{2}\left(\omega t - \frac{\sin 2\omega t}{2}\right)_0^{\pi}\right]^{1/2}$$

$$= \frac{200}{\sqrt{\pi}}\left[\frac{1}{2}\times\pi\right]^{1/2} = \frac{200}{\sqrt{2}}$$

Power dissipiated to resistor

$$P_R = \frac{(V_0)^2_{\text{rms}}}{R} = \left(\frac{200/\sqrt{2}}{50}\right)^2 = 400 \text{ W}$$

SOL 1.9.87 *

Given $f = 20$ kHz

$$D = 0.5$$

Power transferred from source V_1 to $V_2 = ?$

$$\text{Time period } t = \frac{1}{f} = \frac{1}{20\times 10^{-3}} = 50\ \mu\text{sec}$$

$$D = 0.5$$

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$$t_{ON} = 25\ \mu\text{sec},\ t_{off} = 25\ \mu\text{sec}$$

at t_{ON}, energy will stored in inductor circuit

$$v = L\frac{di}{dt}$$

$$100 = 100 \times 10^{-6}\frac{di}{dt}$$

$$\frac{di}{dt} = 10^6$$

$$i = 10^6 t + i(0) \qquad \because\ i(0) = 0$$

$$i = 10^6 t \qquad \ldots(1)$$

$$E = \frac{1}{2}Li^2$$

$$E = \frac{1}{2} \times 100 \times 10^{-6} \times 10^{12} \times 25 \times 25 \times 10^{-12}$$

$$E = 3.1250 \times 10^{-2}\ \text{J}$$

Now power transferred during t_{off}

$$P_t = \frac{3.1250 \times 10^{-2}}{25 \times 10^{-6}} = 12.5 \times 10^2\ \text{W}$$

SOL 1.9.88 Option (B) is correct.

For providing electrical isolation it is necessary to connect a pulse transformer at the output stage of a thyristor triggering circuit.

SOL 1.9.89 Option (A) is correct.

In ac to dc circulating current dual converters if triggering angles are α_1 and α_2 , than it is necessary that

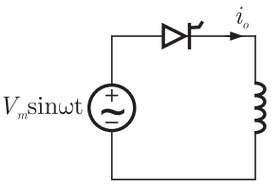
$$\alpha_1 + \alpha_2 = 180^\circ$$

SOL 1.9.90 Option (D) is correct.

Given a half wave Thyristor converter supplies a purely inductive load

Triggering angle $\alpha = 120^\circ$

than extinction angle $\beta = ?$



First we have to draw its output characteristics as shown below

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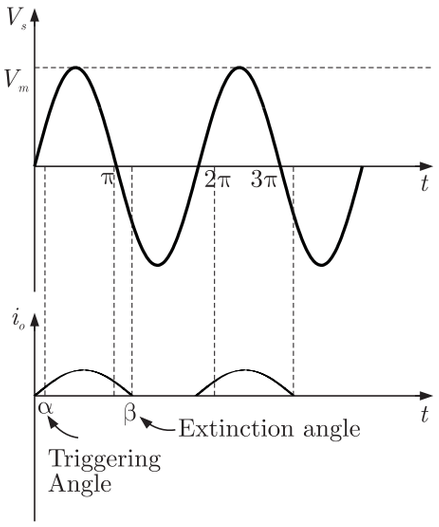

output is given by

$$i_0 = \frac{V_m}{Z}\sin(\omega t - \phi) - \frac{V_m}{Z}\sin(\alpha - \phi)\exp\left(\frac{-R}{\omega L} - \alpha\right) \qquad ...(1)$$

We know at extinction angle i.e. $\omega t = \beta$, $i_0 = 0$

from equation (1), at $(\omega t = \beta)$

$$0 = \frac{V_m}{Z}\sin(\beta - \phi) - \frac{V_m}{Z}\sin(\alpha - \phi)e^{\circ}$$

or $\sin(\beta - \phi) = \sin(\alpha - \phi)$

or $\beta - \phi = \alpha - \phi$

or $\beta = \alpha = 120^{\circ}$

SOL 1.9.91 Option (D) is correct.

$\because$ $f = 50$ Hz

So total time $= \frac{1}{f} = \frac{1}{50} = 20$ msec

Conduction time for each feedback diode in a cycle is being given by

$$t_{\text{conduction}} = \frac{20}{8} = 2.5 \text{ msec}$$

SOL 1.9.92 *

Given a voltage commulated thyristor chopper circuit in figure which is operated at 500 Hz, with 50% duty ratio.

$$I_L = 20 \text{ A(constant)}$$

We have to evaluate

(a) T_{off} for thyristor Th_1

(b) $L = ?$ if peak current through Th_1 is 180% limited

(c) Maximum instantaneous output voltage

$$\text{Turn off time } T_{\text{off}} = \frac{CV_s}{I_L} = \frac{6 \times 10^{-6} \times 100}{20} = 30 \ \mu\text{sec}$$

Peak current through Th_1

$$i_{\text{Th}_1} = I_0 + V_{dc}\sqrt{\frac{C}{L}}$$

$\because$ $i_{\text{Th}_1} = 1.8I_L = 1.8 \times 20 = 36$ A

$$36 = 20 + 100\sqrt{\frac{6 \times 10^{-6}}{L}}$$

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or $$0.16 = \sqrt{\frac{6 \times 10^{-6}}{L}}$$

$$L = \frac{6 \times 10^{-6}}{(0.16)^2} = 2.34 \times 10^{-4} \text{ H}$$

Maximum instantaneous output voltage

$$V_m = 2V_{dc} = 200 \text{ V}$$

SOL 1.9.93 *

Given in figure separately excited dc motor is controlled by varying its armature voltage using 1-ϕ full converter bridge.

Motor voltage constant $K_v = 2.5$ V/rad/sec

Motor Torque $T = 140$ Nm, $\alpha = 60^\circ$

armature current continuous and ripple free.

(a) $I_a = ?$

(b) $N_m = ?$

(c) rms of fundamental component of input current.

(a) $\because$ Motor Torque $T = E_b I_a$ and $E_b = K_v \omega$

Than $K_v \omega I_a = T\omega$

$$I_a = \frac{T}{K_v} = \frac{140}{25} = 50 \text{ Amp}$$

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(b) In dc motor we know

$$I_a = \frac{V_0 - E_b}{R_a}$$

$$E_b = V_0 - I_a R_a$$

$$V_0 = \frac{2V_m \cos\alpha}{\pi} = \frac{2 \times 250\sqrt{2}}{\pi}\cos 60^\circ$$

$$E_b = \frac{500\sqrt{2}}{\pi} \times 2 - 20(0.2)$$

$$E_b = 215.2 \text{ V}$$

$$\omega = \frac{E_a I_a}{T} = \frac{215.2 \times 20}{140} = 30.74 \text{ rad/sec}$$

(c) Rms value of fundamental component of input current

$$I_{sr} = \frac{I_{or}}{\sqrt{2}\left[\frac{1}{\pi}\left((\pi - \alpha) + \frac{1}{2}\sin 2\alpha\right)\right]^{1/2}}$$

$$I_{or} = 56 \text{ Amp}, \ \alpha = 60^\circ$$

$$I_{sr} = \frac{56}{\sqrt{2}\left[\frac{1}{\pi}\left(\pi - \frac{\pi}{3}\right) + \frac{1}{2}\sin 120^\circ\right]^{1/2}}$$

$$I_{sr} = \frac{39.6}{\left(\frac{2}{3} - \frac{1}{4}\right)^{1/2}} = 61.34 \text{ Amp}$$

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10

GENERAL APTITUDE

2012 ONE MARK

MCQ 1.10.1 If $(1.001)^{1259} = 3.52$ and $(1.001)^{2062} = 7.85$, then $(1.001)^{3321}$

(A) 2.23 (B) 4.33

(C) 11.37 (D) 27.64

MCQ 1.10.2 Choose the most appropriate alternate from the options given below to complete the following sentence :

If the tired soldier wanted to lie down, he.....the mattress out on the balcony.

(A) should take (B) shall take

(C) should have taken (D) will have taken

MCQ 1.10.3 Choose the most appropriate word from the options given below to complete the following sentence :

Give the seriousness of the situation that he had to face, his.....was impressive.

(A) beggary (B) nomenclature

(C) jealousy (D) nonchalance

MCQ 1.10.4 Which one of the following options is the closest in meaning to the word given below ?

Latitude

(A) Eligibility (B) Freedom

(C) Coercion (D) Meticulousness

MCQ 1.10.5 One of the parts (A, B, C, D) in the sentence given below contains an ERROR. Which one of the following is **INCORRECT** ?

I requested that he should be given the driving test today instead of tomorrow.

(A) requested that (B) should be given

(C) the driving test (D) instead of tomorrow

2012 TWO MARKS

MCQ 1.10.6 One of the legacies of the Roman legions was discipline. In the legious, military law prevailed and discipline was brutal. Discipline on the battlefield kept units obedient, intact and fighting, even when the odds and conditions were against them.

Which one of the following statements best sums up the meaning of the above passage ?

(A) Through regimentation was the main reason for the efficiency of the Roman legions even in adverse circumstances.

(B) The legions were treated inhumanly as if the men were animals

(C) Disciplines was the armies inheritance from their seniors

(D) The harsh discipline to which the legions were subjected to led to the odds and conditions being against them.

MCQ 1.10.7 Raju has 14 currency notes in his pocket consisting of only Rs. 20 notes and Rs. 10 notes. The total money values of the notes is Rs. 230. The number of Rs. 10 notes that Raju has is

(A) 5 (B) 6

(C) 9 (D) 10

MCQ 1.10.8 There are eight bags of rice looking alike, seven of which have equal weight and one is slightly heavier. The weighing balance is of unlimited capacity. Using this balance, the minimum number of weighings required to identify the heavier bag is

(A) 2 (B) 3

(C) 4 (D) 8

MCQ 1.10.9 The data given in the following table summarizes the monthly budget of an average household.

Category	Amount (Rs.)
Food	4000
Clothing	1200
Rent	2000
Savings	1500
Other expenses	1800

The approximate percentages of the monthly budget **NOT** spent on savings is

(A) 10% (B) 14%

(C) 81% (D) 86%

MCQ 1.10.10 A and B are friends. They decide to meet between 1 PM and 2 PM on a given day. There is a conditions that whoever arrives first will not wait for the other for more than 15 minutes. The probability that they will meet on that days is

(A) 1/4 (B) 1/16

(C) 7/16 (D) 9/16

2011 ONE MARK

MCQ 1.10.11 There are two candidates P and Q in an election. During the campaign, 40% of voter promised to vote for P, and rest for Q. However, on the day of election 15% of the voters went back on their promise to vote for P and instead voted for Q. 25% of the voter went back on their promise to vote for Q and instead voted for P. Suppose, P lost by 2 votes, then what was the total number of voters ?

(A) 100 (B) 110

(C) 90 (D) 95

MCQ 1.10.12 The question below consists of a pair of related words followed by four pairs of words. Select the pair that best expresses the relations in the original pair :
Gladiator : Arena

(A) dancer : stage (B) commuter : train

(C) teacher : classroom (D) lawyer : courtroom

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MCQ 1.10.13 Choose the most appropriate word from the options given below to complete the following sentence :
Under ethical guidelines recently adopted by the Indian Medical Association, human genes are to be manipulated only to correct diseases for which..... treatments are unsatisfactory.

(A) similar (B) most
(C) uncommon (D) available

MCQ 1.10.14 Choose the word from the from the options given below that is most opposite in meaning to the given word :
Frequency

(A) periodicity (B) rarity
(C) gradualness (D) persistency

MCQ 1.10.15 Choose the most appropriate word from the options given below to complete the following sentence :
It was her view that the country's had been ..... by foreign techno-crafts, so that to invite them to come back would be counter-productive.

(A) identified (B) ascertained
(C) exacerbated (D) analysed

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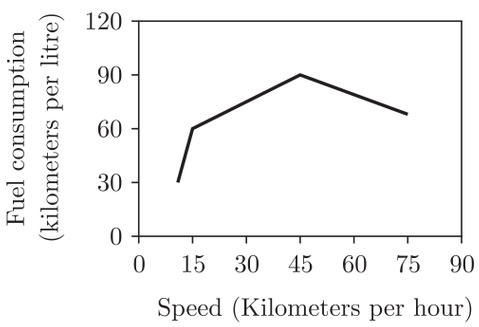
2011 TWO MARKS

MCQ 1.10.16 The fuel consumed by a motor cycle during a journey while travelling at various speed is indicated in the graph below.



The distance covered during four laps of the journey are listed in the table below

Lap	Distance (Kilometres)	Average speed (kilometres per hour)
P	15	15
Q	75	45
R	40	75
S	10	10

From the given data, we can conclude that the fuel consumed per kilometre was least during the lap

(A) P (B) Q
(C) R (D) S

MCQ 1.10.17 The horse has played a little known but very important role in the field of medicine. Horses were injected with toxins of disease until their blood build up

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immunities. Then a serum was made from their blood. Serums to fight with diphteria and tetanus were developed this way.
It can be inferred from the passage, that horses were
(A) given immunity to diseases
(B) generally quite immune to diseases
(C) given medicines to fight toxins
(D) given diphtheria and tetanus serums

MCQ 1.10.18 The sum of n terms of the series $4 + 44 + 444 + ...$
(A) $(4/81)[10^{n+1} - 9n - 1]$ (B) $(4/81)[10^{n-1} - 9n - 1]$
(C) $(4/81)[10^{n+1} - 9n - 10]$ (D) $(4/81)[10^{n} - 9n - 10]$

MCQ 1.10.19 Given that $f(y) = |y|/y$, and q is any non-zero real number, the value of $|f(q) - f(-q)|$ is
(A) 0 (B) -1
(C) 1 (D) 2

MCQ 1.10.20 Three friends R, S and T shared toffee from a bowl. R took $1/3^{rd}$ of the toffees, but returned four to the bowl. S took $1/4^{th}$ of what was left but returned three toffees to the bowl. T took half of the remainder but returned two back into the bowl. If the bowl had 17 toffees left, how many toffees were originally there in the bowl ?
(A) 38 (B) 31
(C) 48 (D) 41

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2010 ONE MARK

MCQ 1.10.21 Which of the following options is the closest in meaning to the word below ?
Circuitous
(A) Cyclic (B) Indirect
(C) Confusing (D) Crooked

MCQ 1.10.22 The question below consist of a pair of related words followed by four pairs of words. Select the pair that best expresses the relation in the original pair.
Unemployed : Worker
(A) Fallow : Land (B) Unaware : Sleeper
(C) Wit : Jester (D) Renovated : House

MCQ 1.10.23 Choose the most appropriate word from the options given below to complete the following sentence :
If we manage to ..... our natural resources, we would leave a better planet for our children.
(A) unhold (B) restrain
(C) cherish (D) conserve

MCQ 1.10.24 Choose the most appropriate word from the options given below to complete the following sentence :
His rather casual remarks on politics.....his lack of seriousness about the subject.
(A) masked (B) belied

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(C) betrayed (D) suppressed

MCQ 1.10.25 25 persons are in a room 15 of them play hockey, 17 of them play football and 10 of them play hockey and football. Then the number of persons playing neither hockey nor football is

(A) 2 (B) 17

(C) 13 (D) 3

2010 TWO MARKS

MCQ 1.10.26 Modern warfare has changed from large scale clashes of armies to suppression of civilian populations. Chemical agents that do their work silently appear to be suited to such warfare ; and regretfully, their exist people in military establishments who think that chemical agents are useful fools for their cause.

Which of the following statements best sums up the meaning of the above passage ?

(A) Modern warfare has resulted in civil strife.

(B) Chemical agents are useful in modern warfare.

(C) Use of chemical agents in ware fare would be undesirable.

(D) People in military establishments like to use chemical agents in war.

MCQ 1.10.27 If $137 + 276 = 435$ how much is $731 + 672$?

(A) 534 (B) 1403

(C) 1623 (D) 1531

MCQ 1.10.28 5 skilled workers can build a wall in 20 days; 8 semi-skilled workers can build a wall in 25 days; 10 unskilled workers can build a wall in 30 days. If a team has 2 skilled, 6 semi-skilled and 5 unskilled workers, how long will it take to build the wall ?

(A) 20 days (B) 18 days

(C) 16 days (D) 15 days

MCQ 1.10.29 Given digits 2, 2, 3, 3, 3, 4, 4, 4, 4 how much distinct 4 digit numbers greater than 3000 can be formed ?

(A) 50 (B) 51

(C) 52 (D) 54

MCQ 1.10.30 Hari (H), Gita (G), Irfan (I) and Saira (S) are siblings (i.e. brothers and sisters.) All were born on 1st January. The age difference between any two successive siblings (that is born one after another) is less than 3 years. Given the following facts :

1. Hari's age + Gita's age > Irfan's age + Saira's age.
2. The age difference between Gita and Saira is 1 year. However, Gita is not the oldest and Saira is not the youngest.
3. There are no twins.

In what order were they born (oldest first) ?

(A) HSIG (B) SGHI

(C) IGSH (D) IHSG

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SOLUTIONS

SOL 1.10.1 Option (D) is correct.

Let $1.001 = x$

So in given data :

$$x^{1259} = 3.52$$

$$x^{2062} = 7.85$$

Again
$$x^{3321} = x^{1259+2062}$$
$$= x^{1259}x^{2062}$$
$$= 3.52 \times 7.85$$
$$= 27.64$$

SOL 1.10.2 Option (C) is correct.

SOL 1.10.3 Option (D) is correct.

SOL 1.10.4 Option (B) is correct.

SOL 1.10.5 Option (B) is correct.

SOL 1.10.6 Option (A) is correct.

SOL 1.10.7 Option (A) is correct.

Let no. of notes of Rs.20 be x and no. of notes of Rs. 10 be y.

Then from the given data.

$$x + y = 14$$

$$20x + 10y = 230$$

Solving the above two equations we get

$$x = 9, y = 5$$

So, the no. of notes of Rs. 10 is 5.

SOL 1.10.8 Option (A) is correct.

We will categorize the 8 bags in three groups as :

(i) $A_1A_2A_3$, (ii) $B_1B_2B_3$, (iii) C_1C_2

Weighting will be done as bellow :

1^{st} weighting $\rightarrow$ $A_1A_2A_3$ will be on one side of balance and $B_1B_2B_3$ on the other.

It may have three results as described in the following cases.

Case 1 : $A_1A_2A_3 = B_1B_2B_3$

This results out that either C_1 or C_2 will heavier for which we will have to perform weighting again.

2^{nd} weighting $\rightarrow$ C_1 is kept on the one side and C_2 on the other.

if $C_1 > C_2$ then C_1 is heavier.

$C_1 < C_2$ then C_2 is heavier.

Case 2 : $A_1A_2A_3 > B_1B_2B_3$

it means one of the $A_1A_2A_3$ will be heavier So we will perform next weighting as:

2^{nd} weighting $\rightarrow$ A_1 is kept on one side of the balance and A_2 on the other.

if $A_1 = A_2$ it means A_3 will be heavier

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$A_1 > A_2$ then A_1 will be heavier

$A_1 < A_2$ then A_2 will be heavier

Case 3 : $A_1A_2A_3 < B_1B_2B_3$

This time one of the $B_1B_2B_3$ will be heavier, So again as the above case weighting will be done.

2^{nd} weighting → B_1 is kept one side and B_2 on the other

if $B_1 = B_2$ B_3 will be heavier

$B_1 > B_2$ B_1 will be heavier

$B_1 < B_2$ B_2 will be heavier

So, as described above, in all the three cases weighting is done only two times to give out the result so minimum no. of weighting required = 2.

SOL 1.10.9 Option (D) is correct.

Total budget $= 4000 + 1200 + 2000 + 1500 + 1800 = 10,500$

The amount spent on saving $= 1500$

So, the amount not spent on saving

$$= 10,500 - 1500 = 9000$$

So, percentage of the amount

$$= \frac{9000}{10500} \times 100\% = 86\%$$

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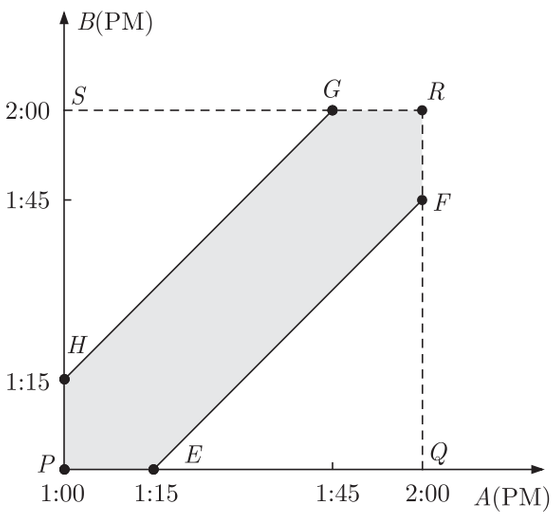
SOL 1.10.10 Option (S) is correct.

The graphical representation of their arriving time so that they met is given as below in the figure by shaded region.



So, the area of shaded region is given by

$$\text{Area of } \square PQRS - (\text{Area of } \Delta EFQ + \text{Area of } \Delta GSH)$$

$$= 60 \times 60 - 2\left(\frac{1}{2} \times 45 \times 45\right)$$

$$= 1575$$

So, the required probability $= \frac{1575}{3600} = \frac{7}{16}$

SOL 1.10.11 Option (A) is correct.

Let us assume total voters are 100. Thus 40 voter (i.e. 40 %) promised to vote for P and 60 (rest 60 %) promised to vote fore Q.

Now, 15% changed from P to Q (15 % out of 40)

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Changed voter from P to Q $\frac{15}{100} \times 40 = 6$

Now Voter for P $40 - 6 = 34$

Also, 25% changed form Q to P (out of 60%)

Changed voter from Q to P $\frac{25}{100} \times 60 = 15$

Now Voter for P $34 + 15 = 49$

Thus P P got 49 votes and Q got 51 votes, and P lost by 2 votes, which is given. Therefore 100 voter is true value.

SOL 1.10.12 Option (A) is correct.
A gladiator performs in an arena. Commutators use trains. Lawyers performs, but do not entertain like a gladiator. Similarly, teachers educate. Only dancers performs on a stage.

SOL 1.10.13 Option (D) is correct.
Available is appropriate because manipulation of genes will be done when other treatments are not useful.

SOL 1.10.14 Option (B) is correct.
Periodicity is almost similar to frequency. Gradualness means something happening with time. Persistency is endurance. Rarity is opposite to frequency.

SOL 1.10.15 Option (C) is correct.
The sentence implies that technocrats are counterproductive (negative). Only (C) can bring the same meaning.

SOL 1.10.16 Option (B) is correct.
Since fuel consumption/litre is asked and not total fuel consumed, only average speed is relevant. Maximum efficiency comes at 45 km/hr, So least fuel consumer per litre in lap Q

SOL 1.10.17 Option (B) is correct.
Option B fits the sentence, as they built up immunities which helped humans create serums from their blood.

SOL 1.10.18 Option (C) is correct.

$$4 + 44 + 444 + \ldots\ldots\ldots\ldots 4(1 + 11 + 111 + \ldots\ldots)$$

$$= \frac{4}{9}(9 + 99 + 999 + \ldots\ldots\ldots\ldots)$$

$$= \frac{4}{9}[(10 - 1) + (100 - 1) + \ldots\ldots\ldots]$$

$$= \frac{4}{9}[10(1 + 10 + 10^2 + 10^3) - n]$$

$$= \frac{4}{9}\left[10 \times \frac{10^n - 1}{10 - 1} - n\right]$$

$$= \frac{4}{81}[10^{n+1} - 10 - 9n]$$

SOL 1.10.19 Option (D) is correct.

$$f(y) = \frac{|y|}{y}$$

Now $$f(-y) = \frac{|-y|}{y} = -f(y)$$

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or $\left|f(q)-f(-q)\right| = \left|2f(q)\right| = 2$

SOL 1.10.20 Option (C) is correct.

Let total no of toffees be x. The following table shows the all calculations.

	Friend	Bowl Status
R	$= \frac{x}{3} - 4$	$= \frac{2x}{3} + 4$
S	$= \frac{1}{4}\left[\frac{2x}{3} + 4\right] - 3$ $= \frac{x}{6} + 1 - 3 = \frac{x}{6} - 2$	$= \frac{2x}{3} + 4 - \frac{x}{6} + 2$ $= \frac{x}{2} + 6$
T	$= \frac{1}{2}\left(\frac{x}{2} + 6\right) - 2$ $= \frac{x}{4} + 1$	$= \frac{x}{2} + 6 - \frac{x}{4} - 1$ $= \frac{x}{4} + 5$

Now, $\frac{x}{4} + 5 = 17$

or $\frac{x}{4} = 17 - 5 = 12$

$x = 12 \times 4 = 48$

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SOL 1.10.21 Option (B) is correct.

Circuitous means round about or not direct. Indirect is closest in meaning to this circuitous

(A) Cyclic : Recurring in nature

(B) Indirect : Not direct

(C) Confusing : lacking clarity of meaning

(D) Crooked : set at an angle; not straight

SOL 1.10.22 Option (B) is correct.

A worker may by unemployed. Like in same relation a sleeper may be unaware.

SOL 1.10.23 Option (D) is correct.

Here conserve is most appropriate word.

SOL 1.10.24 Option (C) is correct.

Betrayed means reveal unintentionally that is most appropriate.

SOL 1.10.25 Option (D) is correct.

Number of people who play hockey $n(A) = 15$

Number of people who play football $n(B) = 17$

Persons who play both hockey and football $n(A \cap B) = 10$

Persons who play either hockey or football or both :

$$n(A \cup B) = n(A) + n(B) - n(A \cap B)$$
$$= 15 + 17 - 10 = 22$$

Thus people who play neither hockey nor football $= 25 - 22 = 3$

SOL 1.10.26 Option (D) is correct.

SOL 1.10.27 Option (C) is correct.

Since $7 + 6 = 13$ but unit digit is 5 so base may be 8 as 5 is the remainder when 13 is divided by 8. Let us check.

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137_8 731_8

$\underline{276_8}$ $\underline{672_8}$

435 Thus here base is 8. Now 1623

SOL 1.10.28 Option (D) is correct.

Let W be the total work.

Per day work of 5 skilled workers $= \frac{W}{20}$

Per day work of one skill worker $= \frac{W}{5 \times 20} = \frac{W}{100}$

Similarly per day work of 1 semi-skilled workers $= \frac{W}{8 \times 25} = \frac{W}{200}$

Similarly per day work of one semi-skill worker $= \frac{W}{10 \times 30} = \frac{W}{300}$

Thus total per day work of 2 skilled, 6 semi-skilled and 5 unskilled workers is

$$= \frac{2W}{100} + \frac{6W}{200} + \frac{5W}{300} = \frac{12W + 18W + 10W}{600} = \frac{W}{15}$$

Therefore time to complete the work is 15 days.

SOL 1.10.29 Option (B) is correct.

As the number must be greater than 3000, it must be start with 3 or 4. Thus we have two case:

Case (1) If left most digit is 3 an other three digits are any of 2, 2, 3, 3, 4, 4, 4, 4.

(1) Using 2, 2, 3 we have 3223, 3232, 3322 i.e. $\frac{3!}{2!} = 3$ no.

(2) Using 2,2,4 we have 3224, 3242, 3422 i.e. $\frac{3!}{2!} = 3$ no.

(3) Using 2,3,3 we have 3233,3323,3332 i.e. $\frac{3!}{2!} = 3$ no.

(4) Using 2,3,4 we have $3! = 6$ no.

(5) Using 2,4,4 we have 3244, 3424, 3442 i.e. $\frac{3!}{2!} = 3$ no.

(6) Using 3,3,4 we have 3334, 3343, 3433 i.e. $\frac{3!}{2!} = 3$ no.

(7) Using 3,4,4 we have 3344,3434,3443 i.e. $\frac{3!}{2!} = 3$ no.

(8) Using 4,4,4 we have 3444 i.e. $\frac{3!}{3!} = 1$ no.

Total 4 digit numbers in this case is

$1 + 3 + 3 + 3 + 6 + 3 + 3 + 3 + 1 = 25$

Case 2 : If left most is 4 and other three digits are any of 2, 2, 3, 3, 3, 4, 4, 4.

(1) Using 2,2,3 we have 4223, 4232, 4322 i.e. . $\frac{3!}{2!} = 3$ no

(2) Using 2,2,4 we have 4224, 4242, 4422 i.e. . $\frac{3!}{2!} = 3$ no

(3) Using 2,3,3 we have 4233, 4323, 4332 i.e. . $\frac{3!}{2!} = 3$ no

(4) Using 2,3,4 we have i.e. . $3! = 6$ no

(5) Using 2,4,4 we have 4244, 4424, 4442 i.e. . $\frac{3!}{2!} = 3$ no

(6) Using 3,3,3 we have 4333 i.e $\frac{3!}{3!} = 1.$ no.

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(7) Using 3,3,4 we have 4334, 4343, 4433 i.e. . $\frac{3!}{2!} = 3$ no

(8) Using 3,4,4 we have 4344, 4434, 4443 i.e. . $\frac{3!}{2!} = 3$ no

(9) Using 4,4,4 we have 4444 i.e. $\frac{3!}{3!} = 1$. no

Total 4 digit numbers in 2nd case $= 3+3+3+6+3+3+1+3+1 = 26$
Thus total 4 digit numbers using case (1) and case (2) is $= 25+26 = 51$

SOL 1.10.30 Option (B) is correct.

Let H, G, S and I be ages of Hari, Gita, Saira and Irfan respectively.

Now from statement (1) we have $H+G > I+S$

Form statement (2) we get that $G-S=1$ or $S-G=1$

As G can't be oldest and S can't be youngest thus either GS or SG possible.

From statement (3) we get that there are no twins

(A) HSIG : There is I between S and G which is not possible

(B) SGHI : SG order is also here and $S > G > H > I$ and $G+H > S+I$ which is possible.

(C) IGSH : This gives $I > G$ and $S > H$ and adding these both inequalities we have $I+S > H+G$ which is not possible.

(D) IHSG : This gives $I > H$ and $S > G$ and adding these both inequalities we have $I+S > H+G$ which is not possible.

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